RECLAMATION

Managing Water in the West

Integrated Pest Management Manual

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

June 2019

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DISCLAIMER

This Integrated Pest Management Manual (IPM Manual) is intended as an introduction to its subject matter and as a reference tool. It does not create or alter policy or otherwise implement any law and should not be cited as a source of authority.

Portions of this IPM Manual make recommendations for actions to treat pests and invasive species. These recommendations were made using the best information available at the time of preparation of this IPM Manual. No statement in this IPM Manual is intended to contradict any law, regulation, statute, or pesticide product label.

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1 INTRODUCTION TO INTEGRATED PEST MANAGEMENT

The U.S. Department of the Interior (DOI), Bureau of Reclamation (Reclamation) is required by Federal law, regulations, Executive Orders, and Policy to control and manage pests and invasive plants and animals. Integrated Pests Management (IPM) assists Reclamation in its mission to deliver water and power. Pests and invasive species should not be underestimated in their impact to project operation and function. Reclamation uses IPM Plans to assist facilities, IPM practitioners, and managers in the diagnosis and treatment of pests and invasive species through implementation of an IPM process.

1.1 Pests

A pest can be defined as any biological organism that causes or has the potential to cause adverse effects to human or natural ecosystem resources. It is important to understand that assessments on the effects of a species presence as undesirable, benign, beneficial, or otherwise as subjective, and both native and non-native species may be classified as pests depending on context and environment. Species considered as pests in one situation may be considered beneficial in another.

Harmful effects of pest species are various and can include human health hazards, degradation of ecosystem processes and habitat value, economic costs, and others. Invasive species can also be harmful to threatened and endangered species by competing for resources, transmitting diseases, interfering with reproduction, or contributing to habitat losses. The impacts of pests to Reclamation's mission are primarily obstruction of water flow, damage to equipment and infrastructure, reductions in facility and operational efficiencies, and increased operation and maintenance (O&M) costs.

1.2 Integrated pest management

Integrated Pest Management is an approach to controlling pests that takes the entire system into account, is well informed regarding scientific information and on-site data collection and produces efficient management of pests by integrating the appropriate tools while minimizing public health effects, environmental impacts, and economic risks.

IPM can also be viewed as a decision-making process for determining if management actions are required, and when, where, and how they should be initiated. It also includes evaluation of pest management treatments, ensuring

achievement of management objectives; all with a comprehensive understanding of the environment and anthropogenic, biological, and ecological systems (figure 1.2). In practice it is a sustainable, science-based, decision-making process that combines biological, cultural, physical, and chemical tools to manage pests in a way that minimizes economic, health, and environmental risks (FIPMCC 2018, table 1.2). IPM should also be considered a strategy under which Best Management Practices and Adaptive Management are developed and utilized for effective and practical solutions that promote conservation through cooperation, communication, and consultation.

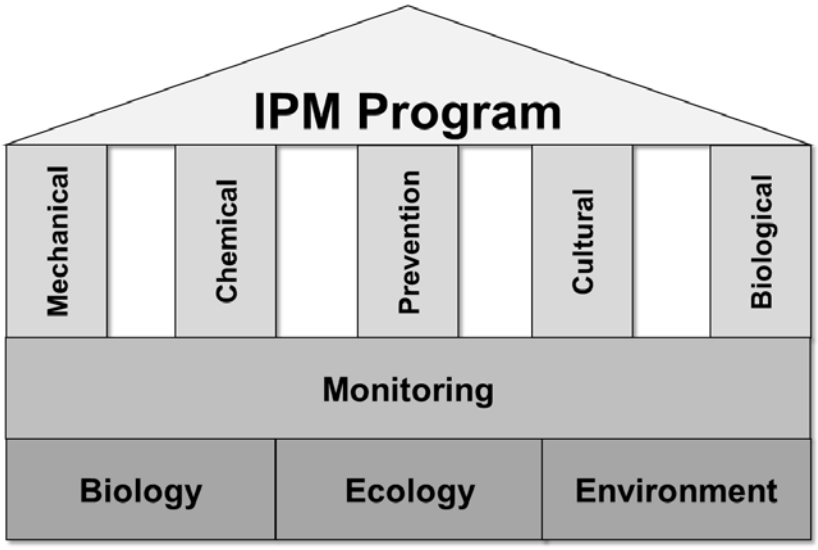

Figure 1.2.—The Integrated Pest Management "house" concept: The foundation of IPM is a comprehensive understanding of the system, built upon by regular monitoring of local conditions, and implemented by the integration of precise control methods.

Table 1.2.—Benefits of a well-planned and executed IPM plan

	Benefits
	Utilize the most cost-efficient methods to control pests
O&M Costs	Prevent damage to infrastructure
	Organize projects to minimize disturbances and outages
	Promote worker and public safety
Health Hazards	Reduce pesticide residues
	Limit worker exposure to pesticides
	Maintain or improve natural resources
Environmental Impacts	Minimize pesticide resistance
	Enhance natural pest suppression for long-term control

The two primary concerns for controlling pest species at Reclamation facilities are: 1) safety of dams and structures, and 2) noxious and/or nuisance pest control around public and non-public facilities. Certain pests must be controlled where they have the potential to cause or contribute toward structural problems on dams and related infrastructure. Noxious and nuisance weeds also have the potential to cause a variety of other problems, including: creating human health and fire hazards, increasing maintenance costs, precluding desirable vegetation, and detracting from aesthetics.

1.3 Overview of a successful IPM program

IPM is a conceptual framework within which site-specific management strategies, partnerships, data collection and assessment, and other related activities are designed and implemented, collectively characterized as an IPM program and guided by a written IPM plan. As a general guideline, development of IPM programs should include the following steps:

- **Baseline Assessment.** Collect and asses all information potentially related to IPM for the area(s) of interest.

- **Determine Roles/Responsibilities.** Designate personnel for IPM planning, implementation, monitoring, and assessment.

- **Set Goals and Objectives.** Address pest management and project performance goals and objectives, both short and long-term.

- **Develop Management Strategies.** Review the IPM toolkit (Section 3), establish thresholds, and develop strategies that describe an effective pest management approach that minimizes disruption to beneficial organisms, hazards to human health, and the environment.

- **Build Partnerships.** Communicate with local communities, decision makers, and technical experts. Maintain relationships and coordinate responses.

- **Implement the Plan.** Implement lowest risk, most effective strategy. Follow applicable laws, regulations, and policies.

- **Identify and Monitor.** Train staff to identify pests and perform regular surveys to detect early infestations. Monitor and record pest populations, pathways of introduction, environmental factors, controls methods implemented, and impacts or changes as a result of pests or controls used. Monitoring is an ongoing activity.

- **Practice Adaptive Management.** Asses monitoring data and evaluate results against objectives. Adapt management strategies as necessary.

- **Document and Disseminate Results.** Keep records of monitoring efforts, management decisions, and treatment effectiveness. Communicate results of the IPM strategy to other decision makers and stakeholders.

2 IPM PLANNING

A central component of a successful IPM program is a written IPM plan, a comprehensive document that establishes conditions and strategies for conducting a safe, effective, and environmentally sound IPM program. IPM plans are dynamic, forward-looking documents with lifespans of about 3 to 5 years. The plan should discuss historic data and current status of the IPM program as well as future plans and new actions necessary to meet the objectives and goals.

2.1 Project areas

Since nearly every situation is unique, designating IPM project areas is an important step in laying out the IPM plan and operating an IPM program. Project areas are typically delineated by facility, operator jurisdiction, or geographic contiguity, but in general should have characteristics similar enough to be managed under a single strategy. Multiple project areas may be covered under a single IPM plan if only minor differences exist and/or if all dissimilarities are addressed individually. Include maps of project area delineations and site descriptions in the IPM plan.

2.2 Data collection

Document the current understanding of primary ecosystem components and characteristics, climate, historic weather patterns and other environmental conditions as well as existing and potential future pest species, their biology, environmental tolerances/habitat attributes, life history, and natural enemies. Details should also be provided for any special status species or critical habitats known to exist within the project area.

An overview of the infrastructure and operations within project areas should also be included or referenced in the IPM plan. More importantly, operational and infrastructure requirements, scheduling, and vulnerabilities that may be impacted by pests/pest management should be noted in the plan.

Communicating with and collecting information from local staff familiar with the project area is highly valuable in creating an IPM plan and should be one of the first steps taken in assimilating background information. Additional surveys and sampling may be necessary to obtain a complete assessment of site conditions and

pest issues. Coordination with technical experts specializing in aspects of IPM can reduce the overall data collection effort and often provides significant improvements for a comprehensive IPM plan. It is recommended to consult with environmental specialists, toxicologists, agronomists, biologists, water quality specialists, surface water hydrologists, and hazardous waste and materials specialists as applicable as part of the IPM program development process.

2.3 Target pests

List all known and potentially problematic pest species. Include identifying characteristics, ecology, habitats, life cycles, reproduction, sources of infestation, description of damage or problems caused, potential management strategies, and any other useful information.

2.4 Partnerships, roles, and responsibilities

Areas managed by different agencies or entities often have different management objectives but are covered under a single IPM plan. It is important to collaborate with and clearly set out strategies, priorities, and roles and responsibilities with all agencies responsible for pest management in the project areas.

All individuals or parties participating in or with authority over any aspect of an IPM program should be identified in the IPM plan, including brief description of their roles and contact information. This may include oversight managers, decision makers, safety officers/emergency response personnel, and partners and stakeholders such as federal, state, or local agencies, water districts, contractors, or others.

2.5 Goals and objectives

Develop and understand your site management objectives and establish short and long-term priorities. Evaluate and revise goals and objectives as new information becomes available to ensure continuous improvement of the IPM program.

2.6 Management strategies

Describe the overall pest management strategy with as much detail as possible. Include discussion of coordination of pest and environmental information with available pest control methods to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment. At a minimum, the management strategy descriptions

should cover action thresholds, specific management areas and pest targets, applicable control techniques and timing, and potential non-target impacts.

The application of pest controls not included in the IPM plan may only be temporarily authorized with appropriate supplemental approval and documentation.

2.6.1 Action thresholds

Define the level of pest infestation that will be tolerated, when control should be triggered, and any exceptions or justifications.

In determining action thresholds, consider the tolerable level of impact from the pest species. As the population grows, the pest may reach a level great enough to cause adverse impacts to the mission, or to cause some form of measurable injury or economic loss. This point of the pest population is known as the injury level. The action threshold is a level of pest population that is below the injury level, and the point where the pest must be controlled to avoid adverse impact, injury, or economic loss. Setting an action threshold is unique for the pest, location, and habitat. Experience with the pest, the location, control methods, and training are needed to determine the injury level and the action threshold for a pest. Once established for a given situation, action thresholds must be stated in the IPM plan for each pest.

Note that the traditional use of action thresholds in the context of IPM is related to agricultural settings where economic costs for pest management can be weighed against potential losses in yield. This concept does not always translate well to situations where benefits of controlling pests are not easily monetized, such as maintaining water flow or preventing infrastructure damage. It is often desirable to set the threshold at a single occurrence of a pest species as part of an overall prevention program, if it has the potential to spread or rapidly, or causes significant harmful effects. Action thresholds can also take other forms, such as a growth height or percent vegetative cover, for example, above which control efforts are initiated.

Determining action thresholds are necessary for each pest species and varies according to the location, situation, life stage of the pest, and pest impact. Many IPM practitioners find setting an action threshold difficult because direct experience of the location, pest, and many other factors are usually required to establish an action threshold. Consulting with other IPM practitioners, conducting a literature review of the pest, and checking previous work records of the site involved should be helpful resources.

2.7 Safety and emergency response

Safety issues and protocols should be evaluated and discussed in the IPM plan, addressing IPM program personnel, training and certification requirements, public communication and awareness, impacts to wildlife or environmentally sensitive areas, or other potential concerns.

Include or reference general operator safety protocols as designated by the local safety office for any heavy equipment operation or hazardous material handling. List required personal protective equipment (PPE) and suggested safety training necessary to implement the IPM plan. Describe adverse incident procedures, list important contact information, and state required documentation and follow up procedures. Reference or include the Job Hazard Analysis (JHA) for pest management work in the IPM plan.

All restrictions in IPM implementation timing or actions necessary for public safety should be noted. Federally listed or sensitive species, critical habitats, or restricted waters within the project areas should be documented; state any necessary protective measures or notification procedures regarding IPM activities.

2.8 Permits and authorizations

All pertinent laws, regulations and ordinances should be stated in the IPM plan, including Federal, State, County, or other local regulations and permitting requirements. Copies of approved permits should be maintained within the IPM plan. Consult Federal and State requirements for listed species and sensitive habitats and obtain all necessary authorizations prior to implementing IPM plan.

2.9 Monitoring

The IPM plan should include a description of monitoring protocols, documentation requirements, and data summaries and interpretations. Monitoring protocols should cover stepwise instructions for all data to be collected; include locations to be monitored, best timing for identification, lists of target pest species, and an example of a data sheet or required fields.

2.10 Adaptive management

The adaptive management process is not required to be specifically laid out in the IPM plan. However, all monitoring data, summary/analyses, and descriptions of adaptations to the IPM program should be recorded in an appendix to the IPM plan annually at minimum and incorporated in the body of the document at the next full revision (at least once every 5 years).

2.11 Documentation and record keeping

Documentation, reporting and record keeping protocols necessary for specific IPM actions should be described in the IPM plan. Blank forms may be included in an appendix or attachment.

3 IPM IMPLEMENTATION

3.1 Monitoring

An accurate pest inventory is used to determine how, when, and where pest management should be initiated for maximum effectiveness. Monitoring objectives should include providing data for evaluating IPM program performance, activating threshold triggers, and informing adaptations of the IPM strategy. It may also be necessary to implement monitoring for the protection of desirable populations and to determine injury or non-target effects.

Frequency and timing of monitoring should typically coincide with targeted pest's lifecycle where they are most easily identified. However, the best timing for treatment may not necessarily coincide with the ideal identification period, and treatments may be more efficient using real-time data. Pairing data collection with treatment application may require additional efforts but can be highly beneficial for controlling high-priority, motile, or rapidly expanding populations.

Many existing monitoring protocols are available as examples to help in developing an IPM monitoring strategy. Outside experts are also a valuable resource in tailoring monitoring plans to specific situations. Methods typically rely heavily on visual observations, but may also include areal or satellite imagery, traps, or sample collection and analysis. Visual observation may be qualitative or quantitative and employ tools such as global positioning systems (GPS) and digital photography depending on target pests, management objectives, and available resources.

3.2 Prevention

Prevention activities to keep pests from entering, establishing and spreading throughout the project areas should be the cornerstone of the IPM program. This is the least expensive and most effective form of pest control and should be considered a top priority.

Prevention efforts should begin with education programs to inform Reclamation staff, customers, peer agencies, and the general public about relevant pest issues. Educational activities can include extension programs, staff briefings, workshops,

training classes, media releases, and informational displays. An informed public can easily report pest sightings through a variety of citizen science apps (e.g. iNaturalist, EDDMapS). Visitors to Reclamation facilities should be informed of "proper prevention behavior" during recreational activities, including using weed-free hay for horses, following the "Clean, Drain, Dry" procedure for boats, and eliminating hosts or sites for insect and disease organisms. Other prevention measures include the use of weed-free certified seed, debris removal and disposal, equipment sanitation, and quarantines.

Prevention does not happen by accident. Plans must be tailored to specific sites and address both preventing the introduction of new pest species and halting further spread of established pests. These goals require an understanding of vectors that can bring in or disperse pests, such as vehicles, equipment, water conveyance, wind, or animals. Certain non-routine activities, like construction or a climatic event should also be considered as potential vectors. A prevention plan will help determine prioritize vectors and how to best address them. Pests may be vectored from across the country or even overseas, and prevention plans should address as many as is reasonable. Prioritizations may be made by known geographic proximity, level of damages caused, or other risk factors.

Detailed information on plant prevention can be found in Section 4: Vegetation Management and animal prevention information can be found in the Section 5: Animal Pest Management and. Additional information on this subject can be found in the *Inspection and Cleaning Manual for Equipment, Vehicles, and Personnel to Prevent the Spread of Invasive Organisms* (Reclamation 2012).

3.2.1 Early detection and rapid response

Even the best prevention efforts will not prohibit each and every pest introduction. Early detection of pests as they establish and immediate, coordinated responses can contain pests before they become too widespread for feasible control. New infestations that are not addressed early will likely require costly and ongoing control efforts. As with prevention, education of pest managers and specialists about species present as well as potential new invaders is critical for effective rapid response.

Rapid response plans need to be detailed in advance in order to be executed in a timely manner once a new pest species is detected. Determine specific courses of action, responsible parties, and communication chain for all pests that have a reasonable probability of introduction.

3.3 Pest control tools

Control and management methods are actions taken to limit, reduce, or eradicate the impact of pests on water system function. Control methods are generally divided into four categories: biological control, chemical control, cultural or environmental control, and mechanical control.

3.3.1 Biological control

Species can become problematic when they are introduced into new areas where few or no natural population limiters exist, leading to uncontrolled outbreaks. Biological control is the introduction or preservation of biotic organisms that act to suppress pest populations. It has the capability to suppress pests in areas that are ecologically sensitive or inaccessible, where pests have large or widespread populations, or where other control options are otherwise impossible or impractical. Biological control ideally reaches a balance or regular oscillation of both pest and biological control populations. If implemented correctly, it can be a long-term suppression tool with low maintenance and costs, although initial establishment costs may be high.

Eradication should not be an expected outcome from biological control as a standalone method. Presence of the pest is necessary to maintain biocontrol agent populations, and it may take 5 to 10 years of actively management before biocontrol populations build to a level that results in noticeable impacts to the pest.

Integration of biological control with other methods can be a successful strategy but must be carefully thought out. Chemical applications for insect control may inadvertently kill biocontrol insects, and vegetation management can remove food sources or habitat reducing survival of the biocontrol agents if not timed appropriately.

3.3.1.1 Classical biological control

Classical biological control is the introduction live predators, pathogens, or parasitoids that have co-evolved with and are highly specific to the target pest species. Non-native biological control agents are only authorized for release after they have been subjected to thorough study and evaluation by U.S. Department of Agriculture (USDA) Agricultural Research Service (and/or its cooperators) and approved by the USDA Animal and Plant Health Inspection Service (APHIS) and each State's Department of Agriculture.

Historically, classical biological control works best on large, dense infestations or monocultures. It has been found to provide good long-term suppression with low overall costs, although initial establishment costs may be high.

3.3.1.2 Augmentation biological control

Augmentation control involves release of biocontrol agents that are not expected to become established and maintain a population on their own. These are general sterile organisms such as triploid grass carp that may not meet environmental safety requirements for classical control but can be effective for a limited period of time (several years) and will not proliferate or cause extensive non-target impacts. Augmentation biological control does not require special permitting or approval.

3.3.1.3 Conservation biological control

Conservation biocontrol is the use of practices to maintain or enhance populations of native existing biological control agents, such as maintaining hedgerows or avoiding chemical application where not necessary. If present, natively occurring biological controls should be identified, their habitats and lifecycles understood, and steps taken to protect them from harm as much as possible.

3.3.1.4 Biological control resources

Biological control agents for weed pests include fish, cattle, sheep, and goats. Successful use of these biological control agents generally requires special planning and expertise. Check with the Reclamation IPM Program Coordinator, (84-53000, Environmental Compliance Division) or your local extension university for information about the habitat requirements, availability, and collection/release methods for any biocontrol agent listed.

3.3.2 Chemical control

Chemical control is the application of any manufactured or extracted compounds (pesticides) to control pests, and includes the use of toxins, repellents, or chemicals that to alter the ability of a pest to complete its life cycle. All chemicals used for pest management must be registered with the Environmental Protection Agency (EPA) and used in accordance with the label.

Pesticides can be an effective and cost-efficient management tool. However, improper use can lead to environmental injury, human health hazards, and pesticide resistance. Chemicals with limited residual action can reduce human exposure and lessen environmental impacts, but the costs may be higher due to requirements for more frequent application. Personal protective equipment, handling and storage requirements, equipment and maintenance must also be taken into account when implementing chemical control.

3.3.2.1 Pesticide selection

Careful consideration of pesticide usage in an IPM program is necessary to provide maximum impacts to target species and cost efficiency while minimizing adverse impacts. In selecting a pesticide, consider the following criteria:

- Activity and selectivity to target pests and non-target organisms.
- Potential to leach, runoff, or otherwise move to non-target areas.
- Degradation pathway and rates (environmental persistence).
- Bioaccumulation, carcinogenic or teratogenic properties.
- Per acre costs.

These characteristics can generally be found on the product label; consultation with IPM or pesticide industry experts can be useful for additional information and site-specific pesticide prescriptions.

Even with an ideal pesticide, care should be taken to use minimal amounts of pesticide to accomplish the pest management objectives for economic and environmental quality reasons. Safety to both the public and workers is a key element of Reclamation chemical control activities.

Pesticide selectivity refers to the toxic effect of the chemical on certain species but not others. Selective pesticides are commonly used to remove pests from crops without injuring the crop species but can also be useful on non-agricultural lands or in aquatic sites. Selectivity depends primarily on the pesticide chemistry but can also be affected by interactions with soil characteristics, water quality, dosage rate, weather, species tolerances, and growth stage. Nonselective pesticides can be used when selectivity is not intended or desirable or can be applied in a selective manner (spot applications) to obtain selective control.

3.3.2.2 Restricted use pesticides

Certain pesticides that have a high potential for adverse effects are classified as “Restricted Use.” This generally includes pesticides that are highly toxic or have a high potential to drift or contaminate ground water. Restricted Use pesticides may only be purchased or applied by certified pesticide applicators or under the direct supervision of a certified applicator (for detailed information on the "Restricted Use" classification, consult 40 CFR Subpart I, 152.160).

Aquatic pesticides rarely remain where applied and are often placed in a Restricted Use category. A limited number of aquatic pesticides are available for use on irrigation systems and require specific knowledge to obtain maximum effectiveness and to prevent damage to crops or other non-target species. See Section 6: Pesticide Safety and Emergency Response for additional information regarding pesticide regulations.

3.3.2.3 Application methods

Selecting the appropriate application method should include label restrictions, treatment objective, site accessibility and topography, size of pest infestation, characteristics of the target and desired species, location of sensitive areas and potential environmental impacts in the immediate vicinity, weather, available equipment, and budget.

Over very large or inaccessible areas, pesticide treatments may be applied aerially by helicopter or fixed-wing aircraft. Aerial applications do not disturb the soil or protective organic layers and are not limited by inaccessibility or rugged terrain. In general, helicopters are more maneuverable than fixed-wing aircraft, more effective in areas with irregular terrain, and more effective for treating specific targets in areas with multiple vegetation types. A common problem associated with aerial application is drift of chemicals off the target site, which may be difficult to predict and manage.

Aquatic treatments in static water can be applied by boat-mounted surface sprayers or injections below the water surface with dragged hoses. For moving water, "slug" treatments are a single application with sufficient dose to provide control as the pesticide moves downstream, or drip treatments may be applied at lower dose over an extended period.

Spot applications are best suited for treatments of small areas, patchy infestations, or at sites that are inaccessible by vehicle, and can be conducted by backpack mounted sprayers or hand-applied granular applications.

Table 3.3.2.3.—Factors affecting the application of pesticides.

Factor	Effect
Climate	Temperature increases may improve the effect of many pesticides. Low humidity will decrease herbicide uptake. Precipitation can wash pesticides away before they can take effect, while many will break down under intense sunlight. Strong winds can blow pesticides to undesired areas.
Life Cycle	Most pests are easier to control early in their life cycle. Herbicides are most effective when applied during the seedling stage. Insect controls for larval forms will differ from adult treatments.
Physical Characteristics	Plant leaves surfaces with waxy cuticles or hairs can inhibit herbicide uptake. Animal pest mobility may affect bait exposure and distribution throughout the population.
Soil Properties	Soil properties such as texture, organic matter, and pH can have complex interactions with pesticide characteristics such as solubility, adsorption, and persistence. These interactions can have severe implications for pesticide performance.
Water	Aquatic pesticide applications can be affected by water quality factors such as pH, bicarbonate alkalinity, suspended solids, and temperature.

3.3.2.4 Pesticide use permits

Necessary approval and/or permits should be obtained in States where required for application of pesticides to water. In addition, certain Federal requirements apply that may not be listed on the pesticide product label, such as the National Environmental Policy Act (NEPA). Refer to Section 6: Pesticide Safety and Emergency Response of the IPM manual for additional information about the Clean Water Act (CWA) and pesticides.

3.3.3 Cultural or environmental control

Cultural or environmental control activities attempt to control pests by limiting some environmental requirement to reduce their vigor or survival. Essentially this method alters the environment or system operations in some way to be less favorable to pests. Examples include winter drawdown in reservoirs or canals to expose weeds to desiccation and freezing, sealing openings in structures to prevent insect or rodent entry, and planting of competitive vegetation for canal right-of-way.

Cultural control often intersects with other control methods. Since it is not a direct treatment to the pest it can generally be considered a preventative control measure. Burning can be c

The more purely cultural control methods include removal of pest habitats, planting canopy species or considered a cultural control as it can modify the soil and competitive species to favor beneficial species but is often categorized as a mechanical method. Encouraging the expansion of predator populations through habitat planting would fall under both cultural and augmentative biological control. changing the mowing height to shade out weed infestations or planting a patch of preferred host plant to draw insect pests away from more sensitive areas. Various system structural modifications, such as lining, riprapping, and piping, while not typically conducted specifically for pest control, can provide the added benefit of removing substrate for pest colonization.

Most environmental modifications require time to take effect. If a pest is already established, cultural control may be applied after mechanical or chemical options have reduced the pest population. Active restoration of desired ecosystems is an integral component of comprehensive long-term prevention and control programs for invasive species that may keep invasive species from causing greater environmental disturbances. Depending on the scale, duration, and frequency of the invasion, restoring the ecosystem to its original condition may not be technically or financially feasible.

3.3.4 Mechanical control

Mechanical control is the periodic removal of pest biomass. This method is almost always temporary and must be repeated annually or even multiple times within a season.

Examples of mechanical control include hand removal, mowing, plowing, grubbing, chaining, or grading. Mechanical methods are often costly due to equipment costs, operation and maintenance of machinery, and disposal of biomass. In aquatic environments these techniques may create problems, since large amounts of debris will move downstream and plug structures. Many plant species, especially aquatic weeds, can also establish new populations from small fragments that float downstream after mechanical removal efforts.

When mechanical control is used, make sure to dispose of waste biomass properly. A pile of plant and root fragments left untreated or composted may contain viable seed or other propagules and will often produce new growth. Waste can be disposed of by burning in areas where it is allowed.

3.4 Integrating control methods

Integrating several management techniques generally results in more effective and efficient pest control. It is rare for a single control method to completely eradicate a pest population. Consider the system as a whole and look at various methods available to suppress pest populations, how they may interact, and potential undesirable outcomes. Methods that may only slightly weaken the pest target should not be disregarded; use of every available tool to approach pest management from multiple angles will always provide better control that a single method.

Examples of integrating control methods includes the use of mowing or burning to prevent seed production and to stimulate new growth to improve the effectiveness of herbicide applications. Biological control agents often take several years to effectively reduce a large population of invasive species but may have appropriate uses at certain disturbed sites. Therefore, chemicals and other control measures are often necessary to prevent the encroachment and spread of a pest during the time required to reestablish desirable vegetation.

3.5 Research

The IPM toolbox is in a continuous state of evolution. New pesticides and changes to existing pesticide regulations, novel invasive species, and the development of new technologies, all necessitate modification of IPM plans. Research in IPM ranges from basic pest and host biology to the development of

new pest management strategies and tools (FIPMCC 2018). Research also assists policy makers in assessing gaps in authority and program policy, and it supports invasive species resource optimization, prioritization, and public outreach efforts. Rapid advances in genetic modification techniques and genome mapping are adding powerful new options to the IPM toolbox. The ability to collect and analyze vast amounts of data will improve the IPM planning process and timing of control efforts.

3.6 Adaptive management

Integrated pest management must continually adapt in response to monitoring data (pest species composition, distribution, impacts, etc.), advances in methods and technologies, and the administrative and regulatory landscape. Monitoring is critical to adaptive management, even in static systems as pests have the capability of developing resistances to pesticides, avoidance behavior, or even modifications to their life cycles.

4 VEGETATION MANAGEMENT

4.1 Plant basics

The plant kingdom is extremely diverse, with well over 200,000 identified species. Plants are categorized into various groups and subgroups depending on the particular discipline. In vegetation management, the vast majority of the plants of interest belong to the category which can reproduce by seed, which excludes ferns, mosses, and lichens.

Useful plant categorization for management purposes includes general habitat (terrestrial or aquatic) or stem form (herbaceous or woody). Subcategories can include growth form (grasses/graminoids versus broadleaf plants/forbs) or life cycle (annual, perennial, or biennial). All these categories have implications to monitoring and management strategies.

4.1.1 Plant habitats

4.1.1.1 Terrestrial

Terrestrial plants include mesic, xeric, and riparian adapted species.
Mesic species have moderate moisture regimes, neither very wet nor very dry, and the majority of terrestrial plants fall into this category. Examples of mesic weeds are Canada thistle (*Cirsium arvense*) and leafy spurge (*Euphorbia virgata*).

Xeric habitats are very dry, and xeric plants have highly adapted life cycles, physiology and morphology in order to conserve limited available water. There are many weeds that do well in these habitats and outcompete desirable plants by developing deep roots and timing growth to wetter months, including cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola* spp.).

Riparian species have higher water requirements than mesic species; their habitats are typically narrow bands along wetted banks but can extend to areas where there is access to groundwater during early growth stages. These species provide vital habitat for migratory and low-trophic species and are often important ecological features in low precipitation areas. Examples of riparian weeds include Russian olive (*Elaeagnus angustifolia*) and tamarisk or saltcedar (*Tamarix* spp.).

4.1.1.2 Aquatic

Aquatic plants have specialized structures that allow them to live in aquatic or water-saturated soil conditions. A considerable number of aquatic weeds are vascular plants, and many are true flowering plants. They can further be subdivided into emergent, submersed, and floating aquatic habitats.

Emergent aquatic plants are rooted in the substrate of ponds, streams, lakes, reservoirs, canals, and ditches, and develop structures that grow above the water surface. Examples are cattails (*Typha* spp.), rushes (*Juncus* spp.), sedges (*Carex* spp.), and smartweeds (*Polygonum* spp.). These species often populate wetted perimeters and shallow areas of water bodies and are also referred to as marginal aquatic plants or tulles.

Submersed plants grow almost entirely underwater, but stalks may reach just above the water surface to flower. They may or may not be rooted in the bottom substrate and are buoyed by air cells in the leaves and stems. Examples include true pondweeds (*Potamogeton* spp.), horned pondweed (*Zannichellia palustris*), watermilfoils (*Myriophyllum* spp.), coontail (*Ceratophyllum demersum*), waterweeds (*Elodea* spp.), hydrilla (*Hydrilla verticillata*), and many more.

Floating plants float on the water surface and are not rooted in substrates. Examples are water hyacinth (*Eichhornia crassipes*), giant salvinia (*Salvinia molesta*), and duckweed (*Lemna minor*).

4.1.2 Plant stem form

The primary difference between woody and herbaceous plants is stem composition and growth. Herbaceous plants have flexible stems while woody plants have a strong, inflexible stems usually covered with a layer of bark. The woody structure is a cellular adaptation that allows these plants to support large

biomass, survive harsh winters and continue growth over many years, forming a new layer of tissue every season. The aboveground biomass of herbaceous plants will typically die back seasonally.

Trees are woody perennial plants with a single main stem or trunk and radiating branches on the upper portion of the plant. They usually stand over 13 feet tall at maturity. Shrubs are woody perennials lacking a main stem, instead having several to many branches arising at ground level. They are usually less than 13 feet tall.

Woody species will generally grow larger and have more extensive root systems than herbaceous species. They can provide benefits for bank stabilization in some cases but may also cause damage from root intrusion and facilitate piping. Herbaceous species are less of a threat to concrete and structures but may still be problematic.

4.1.3 Plant growth forms

4.1.3.1 Graminoids

Graminoids include grasses and grass-like plants such as sedges (Family *Cyperaceae*) and rushes (Family *Juncaceae*). Sedges resemble grasses but have solid stems that are often triangular in cross section. Rushes resemble grasses but have round, flexible, hollow, or spongy stems lacking joints. Grasses have jointed, hollow stems and clusters of small membranous flowers (florets) arranged in spikelets. The leaves of grasses are narrow, upright, and parallel-veined, with fibrous root systems.

4.1.3.2 Broadleaf plants

Broadleaf plants have two seed- leaves (dicotyledons or dicots). These species comprise the larger of the two growth form categories. They have broad, net-veined leaves and a taproot or a coarse, branched root system. These plants will die back seasonally (senescence).

4.1.3.3 Non-vascular plants

Non-vascular plants include bryophytes (mosses, liverworts, and hornworts). Green algae can also be considered a non-vascular plant but is typically addressed separately since management strategies are not similar. Some bryophytes can be visually similar in appearance to some non-vascular aquatic plants but are not true flowering plants and do not produce seed; reproduction occurs via spores. Problematic bryophytes that are well established have limited control options and can be difficult to control.

4.1.3.4 Green algae

Green algae are non-vascular plants that range in size from microscopic free-floating cells to macroscopic filaments that form mats or clusters. Some genera, such as *Chara* or *Nitella*, appear similar to rooted vascular plants, but do not have roots and instead attach to substrates with rhizoid appendages.

Blue-green algae or cyanobacteria are considered separately from green algae. They are not plants, but photosynthetic bacteria. This is a very diverse group which includes unicellular and filamentous species. Examples of colonial blue-green algae seen on irrigation systems are *Nostoc* and *Phormidium*. Harmful algal blooms (HABs) caused by large colonies of blue-green algae release toxins that can affect fish, human health, and recreation activities. Blooms tend to occur in less turbulent waters that have high amounts of nutrients. Chemical control of HABs is possible but typically expensive. Potential chemicals include copper sulfate, calcium hypochlorite, and simazine. If a HAB occurs, access to the affected water must often be restricted, leading to significant economic loss.

4.1.4 Plant lifecycles

4.1.4.1 Annuals

Annual plants live for only one growing season and put a large proportion of energy into seed production. Aboveground growth is rapid and root systems are relatively small. The prolific seed production of annuals and variations in seed dormancy means these plants may continue to appear even after many years of intensive management.

Winter Annuals germinate in fall or early winter, remain dormant over the winter, and complete their life cycle early the following summer. Prickly lettuce (*Lactuca serriola*) and cheatgrass are common winter annuals.

Summer Annuals germinate in the spring or summer and complete their life cycle by fall. Examples of summer annuals include yellow starthistle (*Centaurea solstitialis)*, puncturevine (*Tribulus terrestris*), Russian thistle (*Salsola tragus*), redroot pigweed (*Amaranthus retroflexus*), wild oat (*Avena fatua* L.), and barnyardgrass/watergrass (*Echinochloa cus-galli*).

4.1.4.2 Biennials

Biennial plants live for 2 years. During the first year, they typically produce rosettes of basal leaves and taproots. They send up flowering stalks (“bolt”) the second year, produce seeds, and die. Desirable biennials are relatively uncommon. However, many invasive weeds are biennials, including musk thistle (*Carduus nutans* L.), scotch thistle (*Onopordum acanthium*), burdock (*Arctium sp.*), and some knapweed species.

Biennials usually germinate in the spring, develop to a rosette stage in the fall, overwinter, and send up a seed stalk the following spring. They are controlled quite easily by application of a suitable herbicide during the seedling stage. A fall application of a suitable translocated herbicide during the fall rosette stage generally provides good control. This subjects the target weeds to three successive stresses: (1) herbicidal stress, (2) winter weather, and (3) heavy demand for nutrients caused by the rapid growth period the following spring.

4.1.4.3 Perennials

Perennial plants live for many years. Flowering and reproduction may be delayed until later stages of maturation. Perennials can afford to direct more energy to long-term establishment and typically have more extensive root systems. These species are usually the most desirable for plantings. They are the most resistant to control with herbicides or mechanical and cultural methods. Woody perennials, which include tree and brush species, are good examples of long-lived perennials where aboveground parts survive from year to year. Perennials may spread by seeds, roots, aboveground stems (stolons), and by rhizomes (belowground stems) (McHenry et al., 1972).

Simple Perennials spread by seed. They do not have specialized vegetative structures for spreading. However, injured or cut pieces may produce new plants. The roots are large and fleshy. Examples are dandelion (*Taraxacum officinale*), curly dock (*Rumex crispus*), and purple loosestrife (*Lythrum salicaria*) (Fischer et al., 1976).

Creeping Perennials reproduce by creeping underground stems (rootstocks or rhizomes), as well as by seed (Swan et al., 1976; McHenry et al., 1972). Examples are field bindweed (*Convolvulus arvensis*), leafy spurge (*Euphorbia esula*), Canada thistle (*Cirsium arvense),* Russian knapweed (*Rhaponticum repens*), bermudagrass (*Cunodon dactylon*), Johnson grass (*Sorghum halepense*), and reed canary grass (*Phalaris arundinacea*).

4.1.4.4 Atypical life cycles

Life cycles for some plant species are not absolute and plants may exhibit uncharacteristic behaviors between different localities or even sporadically at a single location. Climate and duration of growing season are usually the primary influence. Annuals may shift between summer and winter germination, and biennials may behave as short-lived perennials.

Some plants, such as reed canary grass (*Phalaris arundinacea*) may go into a summer dormant period; chemical control will not be effective when this occurs. IPM practitioners should be alert to such potential situations and be able to plan and adjust their management programs accordingly.

4.1.5 Plant development stages

4.1.5.1 Seedling stage

The seedling stage of growth is the same for annual, biennial, and perennial weeds. Seedlings are small and succulent, and less energy is required for control at this stage than at any other stage. Logically, the best time to apply herbicides is in the spring-summer for summer annuals and fall-winter for winter annuals.

4.1.5.2 Vegetative stage

Plant energy at this stage is being used for growth of stems, leaves, and roots. Control is still feasible but more difficult than at the seedling stage. Perennial plants will draw stored energy from roots during this stage.

4.1.5.3 Flowering plant stage

Flowering stages signify a stoppage or significant reduction of vegetative growth, as plants shift their energy to seed production. Chemical control for annual weeds and grasses may not be practical at this time, due to the significant biomass and lowered rates of plant metabolism. However, control efforts to destroy seed or prevent viable seed production at this stage may be a desirable goal.

4.1.5.4 Seed set (maturity) stage

Maturity and seed set completes the annual life cycle. Chemical control is not effective at this stage. For perennials; chemical control may be effective at controlling regrowth the following year.

4.1.6 Reproductive strategies

Seed reproduction is found in all groups of gymnosperms and angiosperms. Seeds may be dispersed by wind, water, animals, or humans. Some seeds may require special treatment or conditions such as fire, freezing temperatures, or passage through the gut of an animal in order to break physiological or seed coat dormancy mechanisms, permitting germination.

Vegetative reproduction is the initiation of new plants from root shoots, stems or other specialized vegetative fragments. Many shrubs and a few trees spread by shoots from which new stems can arise. Often, the parent plant must be grazed, clipped, burned, or injured in some way to initiate sprouting. Most herbaceous plants reproduce by seed, but many perennials have developed additional strategies for propagation. Vegetative reproduction can be highly problematic with aquatic weeds where viable fragments can travel downstream and spread the population.

4.1.7 Seasonal growth

Seasonal growth patterns are important considerations, especially for grasses. Two general patterns are recognized, termed cool season and warm season.

Cool season plants begin their growth in late winter or early spring and flower in the early summer. They may enter dormancy during summer heat and resume growth or flower again in the fall if adequate moisture is available.

Warm season plants begin their growth in late spring or early summer and flower in late summer or early fall, usually entering dormancy with the onset of winter.

4.2 Identification and management guide

This is intended as a quick reference and does not reflect all the invasive plants currently identified by the USDA, APHIS, USFWS, or individual states. Check your state or regional guides for a comprehensive list of invasive or pest species.

4.2.1 Algae

Aquatic Algae (*Cladophora* spp., *Ulothrix* spp., *Oedogonium* spp., *Stigeoclonium* spp., *Oscillatoria* spp., and *Phormidium* spp.)

- **Chlorophyta (green algae) –** algae that produces photosynthetic pigments (chlorophyll a, b, c and xanthophyll) that can be motile or nonmotile, has a central vacuole, pigments contained in plastids that vary in shape in different species, and a two layered cellulose and pectin cell wall.

- **Chromophyta (brown algae) –** algae that produces photosynthetic pigments (chlorophyll a, c, Beta carotene) that have a larger and smaller flagellum. Multicellular, sexual and asexual reproduction capability.

- **Cryptophyta (biflagellate) –** any of several genera of small biflagellate algae occurring in fresh and salt water. Contains pigments found elsewhere only in red algae and cyanobacteria. Reproduces asexually in either motile or nonmotile state. Can be considered protozoan rather than algae in some cases.

- **Pyrrophyta (dinoflagellate) –** single-celled aquatic organism bearing two flagella of difference sizes and having plant and animal characteristics. Primarily marine but can be found in fresh water habitats. Can cause red tides.

- **Euglenophyta (photosynthetic protists) –** single-celled flagellated microorganism featuring plant and animal characteristics. Euglena live in fresh and brackish water rich in organic matter and can be found in moist soils. Can be considered protozoan or algae.

- **Cyanobacteria (blue-green algae) – see Green Algae (Section 4.1.3.4)**

- **Rhodophyta (red algae) –** predominantly marine algae, often near shore lines. Reproduces sexually in a non-motile form.

Identification. Algae are a large and diverse group of simple, typically autotrophic organisms, ranging from unicellular to multicellular forms. They are photosynthetic like plants and "simple" because their tissues are not organized into the many distinct organs found in land.

Ecology. Algae can be found in reservoirs and water distribution systems. Algae may impact conveyance systems by restricting water flows for municipal, industrial, agricultural, recreation, and wildlife uses. In addition, algae can impart unpleasant taste and odor to drinking water, increase the biological oxygen demand, and potentially promote habitat where disease carrying vectors can breed. Algae should be treated when it interferes with recreation areas, municipal drinking supplies, and water distribution systems.

4.2.1.1 Control methods

Control will vary depending upon the type of algae. Some chemicals that are effective include: copper sulfate, copper complexes, xylene, acrolein, endothall.

4.2.2 Submersed aquatic weeds

4.2.2.1 American pondweed (Potamogeton nodosus)

Identification. A native plant and one of the most common species of pondweed in the United States. *Potamogeton nodosus* and a few other *Potamogeton* species have relatively large floating leaves and broadened underwater leaves 1 cm (0.4 inch) or wider. The rhizomes of American pondweed are whitish with reddish blotches. The stems are branched and up to 2 m (6.56 feet) long. The plants have leaves of two types; the submersed leaves are alternate, thin, linear-lanceolate or sometimes broader, 8 to 20 cm (3 to 8 inches) long and 1 to 3 cm (0.4 to 1.2 inches) wide and have petioles 2 to 13 cm (0.8 to 5.1 inches) long. Stipules are conspicuous, brownish, and 2 to 7 cm (0.8 to 2.8 inches) long. The floating leaves sometime appear opposite, thickened, coriaceous, lenticular to elliptic in shape, 3 to 12 cm (1.2 to 4.7 inches) long and up to 4.5 cm (1.8 inches) wide.

Ecology. American pondweed grows in lakes, reservoirs, ponds, canals, swamps, streams, and small rivers. Although it produces viable seed, the primary method of regrowth is from winter buds that develop in chains on the terminals of horizontal stems during fall months. These winter buds are utilized by waterfowl as a food source. American pondweed develops dense colonies in shallow areas of lakes, ponds, and reservoirs. These dense colonies can restrict access to various facilities and recreational areas. In the Western United States, this plant can restrict waterflows in irrigation canal systems.

Figure 4.2.2.1.—*Potamogeton nodosus* (Graves Lovell, Alabama Department of Conservation and Natural Resources, Bugwood.org).

4.2.2.1.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal.

Cultural or Environmental Control. Reservoir drawdown; liners, shading, benthic, and bottom barriers.

Biological Control. Triploid grass carp.

Chemical Control. Copper complexes, xylene, acrolein, endothall, fluridone, diquat dibromide, 2,4-D, triclopyr.

4.2.2.2 Brazilian elodea (Egeria densa)

Identification. A submersed perennial; leaves and stems are generally bright green (often dark green when below the surface of the water) and the short internodes give this plant a very leafy appearance. Leaves are 1-3 cm long, 5 mm wide, minutely serrated (needing magnification), and found in whorls of four to eight. Stems are erect, cylindrical, simple or branched, and grow until they reach the surface of the water, where they form dense mats. Flowers have three petals

which are white (18-25 mm) and float on or rise just above the water's surface on a slender peduncle. Slender roots are unbranched and typically a white to pale color. The flowers are significantly larger than the flowers of Hydrilla and Elodea. It is usually rooted but can be found as a free-floating mat.

Figure 4.2.2.2.—*Egeria densa* (Kristian Peters, commons.wikimedia.org).

Ecology. Inhabits mild to warm freshwater, and occurs at depths of up to 7 m. It can survive in water with a temperature range of 3-35 °C. The plant can overwinter as seeds, dormant shoots, or semi-dormant shoots until temperatures rise above 15°C. It also has a low light requirement and can thrive in turbid environments.

Egeria densa is capable of vegetative fragmentation, in which stems break off from the parent and disperse. Stem fragments then take root or grow as free-floating mats. This plant is widely sold for aquariums as a good "oxygenator" plant. It is also dispersed as fragments on boat trailers and recreational gear, or by water flow.

4.2.2.2.1 Control methods

Mechanical or Physical Control. Physical removal can be problematic since it can disperse by fragmentation.

Cultural or Environmental Control. Dewatering or drawdown.

Biological Control. Triploid grass carp.

Chemical Control. Copper complexes, acrolein, endothall, fluridone, diquat dibromide.

4.2.2.3 Coontail (Ceratophyllum demersum)

Identification. Coontail is a native aquatic plant and the most widespread of the three species of *Ceratophyllum* in the United States. Other species of *Ceratophyllum* in the United States are *C. echinatum* and *C. muricatum*.

Figure 4.2.2.3.—*Ceratophyllum demersum* L.(Photograph courtesy of Rene Reyes, Mid-Pacific Regional Office, Reclamation).

This genus is comprised of perennial plants growing beneath the water surface. Plants produce only one branch per node. This is a rootless plant that in early season grows upright, with the lower portion anchored in the bottom mud. In late season, the plants are found floating near the surface. The finely divided leaves are produced in whorls at stem nodes. The individual leaf is cut into two to four forked divisions with occasional tooth-like projections on the margin. The stem internodes are shortened toward the tip, giving the shoot an appearance of a bush tail; hence, the common name “coontail.” Flowers and fruits are produced singularly in the leaf axil whorl. The fruit is rarely seen.

This plant can be confused with certain submersed water buttercups without some scrutiny. The two plants can be distinguished by the definite whorled leaf attachment and forked division of *Ceratophyllum*, unlike the fan-shaped submersed leaves of buttercup.

Ecology. Often weedy and reported as tolerant of fluctuating water levels and moderate turbidity. While not generally considered a serious submersed macrophyte, it is often seen in irrigation systems and can be an aquatic pest in small laterals and new systems.

Vegetative overwintering is accomplished by thickening and shortened shoot tips that develop late in the season and break off, sinking to the bottom substrate to vegetate during favorable growth periods. The primary method of reproduction in coontail is by fragmentation.

4.2.2.3.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal. Dredging (aqua mogs); total acreage removed depends on various factors.

Cultural or Environmental Control. Reservoir drawdown, long term desiccation.

Biological Control. Triploid grass carp.

Chemical Control. Acrolein, endothall, fluridone, diquat dibromide, 2,4-D.

4.2.2.4 Curly-leaf pondweed (Potamogeton crispus)

Identification. A submersed aquatic plant with no floating leaves. Leaves are attached directly to the stem, have a wavy appearance, and are olive-green to reddish-brown. Leaves are alternate and are 4-10 cm in length and 5-10 mm wide. Leaf tips tend to be rounded or blunt. Rhizomes are pale yellow or reddish. Small flowers with greenish-brown or greenish-red sepals appear on a spike above the waterline producing 3-4 fruits per flower.

Figure 4.2.2.4.—Potamogeton crispus (Paul Skawinski, Aquatic Plants of the Upper Midwest).

Ecology. Survives the winter as whole, intact leafy plants, even under thick ice and snow cover, and grows rapidly in the early spring when water temperatures are cool (10-15°C). In early June plants flower and fruit, then die back by mid-July.

Can survive and grow at very low light levels and low water temperatures (1-4°C). It can be found in deep water if there is good light penetration. *P. crispus* may provide wildlife habitat and a source of macroinvertebrate food in low-light

waters where other plants struggle to grow. Curly-leaf pondweed can outcompete native species, especially in the early spring, and large infestations can impede water flow.

Curly-leaf pondweed is present in most of the United States. It has been spread through intentional planting, and through fragment dispersal by boats and migrating waterfowl.

4.2.2.4.1 Control methods

Mechanical or Physical Control. Dredging, sediment removal, hand removal, harvesting, rotovation. Can regrow from fragments/roots.

Cultural or Environmental Control. Reservoir drawdown; liners, shading, benthic, and bottom barriers.

Chemical Control. Copper complexes, endothall, fluridone, diquat dibromide.

4.2.2.5 Elodea waterweed (elodea canadensis)

Identification. A native plant and one of three species of Elodea found in the United States. It is commonly referred to as waterweed, water-thyme, or ditch-moss. It is a perennial submersed aquatic, rooted or drifting free when broken loose, very brittle, and easily fragmented. The slender stems of Elodea branch readily into paired forks, with three or four whorls of leaves at each stem node. Individual leaf bases are somewhat clasping, forming a continuous ring around the stem. Leaf margins are small toothed. Male and female flowers are borne on separate plants. The pistillate or female plant is the one seen most often, producing leaf whorls that are denser with shorter stem internodes than those on the male plant. The flower is produced quite often on the end of thread-like shoots that grow to the water surface.

Figure 4.2.2.5.—*Elodea canadensis*. (Photo credit: https://en.wikipedia.org/wiki/Elodea_canadensis).

Ecology. Propagates from vegetative buds produced on the terminal ends of shoots and by plant fragmentation. These vegetative buds overwinter on bottom muds. This plant will survive and grow in a completely floating state, although it grows more rapidly when rooted in soil. It is common to all areas of western irrigation systems and grows in patches in both large and small laterals. The plant grows in lakes, ponds and slowly moving water in rivers, canals, and streams, and is sometimes found in slightly brackish coastal waters. Plants die back in autumn, and spring regrowth occurs from underground stems crowned by roots or winter buds. Dense populations can reduce water temperatures and oxygen concentrations.

4.2.2.5.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal.

Cultural or Environmental Control. Reservoir drawdown; liners, shading, benthic, and bottom barriers.

Biological Control. Triploid grass carp.

Chemical Control. Copper complexes, xylene, acrolein, endothall, fluridone, diquat dibromide.

4.2.2.6 Eurasian watermilfoil (Myriophyllum spicatum L.)

Identification. *M. spicatum*, like the northern watermilfoil (*M. sibericum*), is completely submerged, except for the flower spikes. The stems are branched slightly and can vary in color from a pale greenish-yellow to a full pink. The leaves are separated into 12 to 24 pairs of filament-like divisions and develop on the stem, usually four in a whorl. Northern watermilfoil leaves are similar but usually have 14 or fewer pairs of divisions. The flowers are small and are usually in whorls of four along a slender terminal spike, which extends above the water surface. All but the lower two to four whorls of floral bracts have smooth edges and are shorter than the flowers and fruit. The lower floral bracts have comb-like or serrated edges and are longer than the fruit. The nut-like fruit of the Eurasian variety exhibits long periods of dormancy and erratic germination.

Ecology. A highly invasive species that colonizes reservoirs, lakes, ponds, streams, small rivers, and brackish waters of estuaries and bays. Stems of Eurasian watermilfoil near the surface branch profusely and often form a dense canopy that reduces light availability for "understory" or native species. This plant spreads asexually by fragmentation, and long-range dispersal is generally through mechanical or autofragmentation, which occurs after flowering toward the end of the growing season. This plant produces multiple other plants from stolons once it is established.

Figure 4.2.2.6.—*Myriophyllum spicatum.* (Photograph courtesy of Rene Reyes, Mid-Pacific Regional Office, Reclamation).

Eurasian watermilfoil grows rapidly from the bottoms of lakes or rivers and reaches to the water surface. Usually, it is found in waters less than 6 m (20 ft) deep, but it may also be found in deeper waters. It can grow in irrigation canals and laterals, but it is not widespread in those systems. It is a serious aquatic pest, much more so than the common native and Brazilian *Myriophyllum* species. It spreads quite rapidly, grows relatively fast, and is very difficult to control.

Fragments of milfoil can be transported from one water body to another, when fragments become attached to a boat trailer. It is a threat to both health and recreation. When it becomes established in colonies, it produces breeding environments for mosquitoes, fouls motorboat propellers, entangles fishing lines, ruins swimming and water-skiing areas, and limits other water uses. Dense beds of Eurasian watermilfoil can be dangerous to swimmers and should be avoided.

Humans (via fragmentation created by recreational activities), migratory waterfowl, and wave action can spread milfoil. During the fall and winter, the plant dies back and the fragmented sections wash ashore, where the densely piled material decomposes and produces offensive odors and unsightly messes. Beach areas become fouled, and recreational uses may cease.

4.2.2.6.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal. Can disperse by fragmentation.

Cultural or Environmental Control. Reservoir drawdown; desiccation will affect vegetative structures (rhizomes, stems).

Biological Control. Triploid grass carp, *Acentria ephemerella* - moth, *Parapoynx obscuralis* - moth.
Chemical Control. Copper complexes, endothall, fluridone, diquat dibromide, 2,4-D, triclopyr.

4.2.2.7 Horned pondweed (Zannichellia palustris)

Identification. Native species that is widespread throughout the US and Canada. Leaves of horned pondweed are much narrower and thread-like and arranged on the stems in an opposite manner, while those of sago pondweed develop from the stem in an alternate pattern. This plant develops a dense, creeping system of horizontal stems that are shallowly rooted with sparsely branching stems. The plant gets its name from the recurved horn-like beaked fruit, which is usually found in threes or fours with very short fruit stems. Fruits and flowers are produced in the leaf axil. The flowers are small, axillary, and lack sepals or petals. This plant does not produce vegetative overwintering structures and is carried through adverse growing conditions and disseminated by seed.

Figure 4.2.2.7.—*Zannichellia palustris* (Maryland Department of Natural Resources).

Ecology. Widespread aquatic plant that can most often be observed in spring or early summer, preceding the growth of other, more vigorous pondweeds, although it will grow in association with true pondweed. This plant can tolerate excessively cold water and can often be seen growing as small tufts on the bottom of streams and canals of northern latitudes during winter months.

Horned pondweed is not reported to be a major problem in the United States. This plant can grow with other submersed species, such as naiads and narrow- leaved pondweeds, which may cause problems in some areas. The seeds of this species are an important food for waterfowl.

4.2.2.7.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal. Dredging (aqua mogs); total acreage removed depends on various factors.

Cultural or Environmental Control. Reservoir drawdown; desiccation will affect vegetative structures (rhizomes, stems).

Biological Control. Triploid grass carp.

Chemical Control. Copper complexes, endothall, fluridone, diquat dibromide, 2,4-D, triclopyr.

4.2.2.8 Hydrilla (Hydrilla verticillata)

Identification. An extremely prolific plant that has infested millions of acres of lakes, rivers, and irrigation systems throughout the US. Hydrilla is now found in many areas of the world, including numerous areas along coastal States from the southeast to northwest portions of the United States. Hydrilla looks very similar to Brazilian elodea (*Egeria densa*) and waterweed (*Elodea canadensis*).

Hydrilla is a submersed perennial that but sometimes may behave as an annual. This plant produces horizontal stems (rhizomes) in the substrate, forming vegetative tubers at the end of these structures under certain conditions. Under certain conditions, bulb-like structures called turions form in leaf axils. Stems can be up to 8.5 m (29 ft) long and can grow to the surface of the water. Leaves are one-nerved sessile, whorled, mostly five or more, and shorter than 1 cm (0.6 inch) long. Leaf margins are serrated and teeth are visible to the eye. The midrib on the upper surface is often tinged with red; the underside usually has one- to three-cell sharp teeth or spines along the central vein.

Flowers are unisexual, growing from the leaf axil. Flowering hydrilla can be monoecious or dioecious. The flowers are small; less than 6 mm (0.25 inch) in diameter, and translucent to white. Female flowers are produced in the fall and are on long thread-like stalks. Male flowers are solitary, small, on short stalks in the leaf axil, and break off as buds.

Figure 4.2.2.8.—*Hydrilla verticillata* royle. (South Carolina Department of Natural Resources.)

Ecology. Hydrilla is a serious aquatic pest. It propagates rapidly, is adaptive to many different environments and climates, and is so vigorous and competitive that it may “take over” a water system, crowding out other aquatic plant species.

Its array of reproductive methods gives hydrilla a particularly formidable ability to spread. This noxious aquatic weed is probably the worst aquatic weed in the United States. Plants form large, dense populations, which restrict flows, impact water quality, displace native species, and reduce access to recreational sites. This plant also spreads from lake to lake by small fragments that are attached to boats and boat trailers.

4.2.2.8.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal.

Cultural or Environmental Control. Reservoir drawdown; liners, shading, benthic, and bottom barriers; screening of substrate to remove tubers/winterbuds.

Biological Control. Triploid grass carp, *Hydrellia pakistanae* - fly, *Hydrellia balciunasi* - fly, *Bagous affinis* - weevil, *Bagous hydrillae* - weevil.

Chemical Control. Copper complexes, acrolein, endothall, fluridone, diquat dibromide.

4.2.2.9 Parrotfeather (Myriophyllum aquaticum)

Identification. Stems of parrotfeather are moderately elongated, relatively stout, and partially submersed with a considerable portion of the leafy branches extending up to 20 cm (8 inches) above the water surface. Leaves are in whorls of 3 to 6 and pinnately dissected with 6 to 18 linear-filiform divisions on each side of the leaf. On the erect stem, leaves are bright green and 2.5 to 5 cm (1 to 2 inches) long and feather-like. Leaf divisions are 4 to 8 mm (0.15 to 0.3 inch) long toward the leaf apex. Female flowers on North American plants are whitish and found in the axil of unreduced leaves.

Figure 4.2.2.9.—*Myriophyllum aquaticum* (André Karwath, commons.wikimedia.org).

Ecology. Native to South America, parrotfeather is sporadically naturalized across much of the United States, likely as a result of plants escaping or being discarded from aquaria or ornamental pools. Its spread has been expanded intentionally by placement in water bodies to provide a source of plants for sale. This plant is found in slow-moving water; edges of streams, lakes, ponds, irrigation ditches and drains, canals, sloughs, and spring-fed runs. Parrotfeather propagates from creeping rhizomes found in the substrate, which can give rise to multiple stems. Parrotfeather forms dense populations that can completely colonize small ponds and sloughs and impede waterflow in ditches and irrigation canals. This plant spreads by fragmentation. It can outcompete and replace native plant species that have more value to fish and wildlife.

4.2.2.9.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal. Dredging (aqua mogs); total acreage removed depends on various factors.

Cultural or Environmental Control. Reservoir drawdown; long-term desiccation for best results; will affect vegetative structures (rhizomes, stems)
Biological Control. Triploid grass carp.

Chemical Control. Endothall, fluridone, diquat dibromide, 2,4-D, triclopyr.

4.2.2.10 Sago pondweed (Stuckenia pectinatus)

Identification. Sago pondweed is a native aquatic plant and occurs throughout most of the United States. This plant was formerly known as *Potamogeton pectinatus*. Sago pondweed is a perennial and has thin, creeping rhizomes that are matted and often end in vegetative structure called a tubers. The stem is slender, about 1 millimeter (mm) (0.05 inch) in diameter, simple at the base, but heavily branched toward the summit. All the leaves are submersed, linear to filiform, 3 to 10 cm (1 to 4 inches) long, and about 1 mm (0.05 inch) wide. Each leaf has one to three nerves and an acute to attenuate apex.

Because of the extensive rhizome runner and tuber development of this species, a single plant spreads over a considerable area. A large, vigorous form of the species is often referred to as giant sago pondweed (Otto et al., 1980). Flowering stalks (peduncles) arise from the base axils and are 3 to 10 cm (1 to 4 inches) long. The flowers are sessile, in whorls of two to five, and on spikes 1 to 4 cm (0.4 to 1.6 inches) long. Fruits are plump, 2.5 to 4 mm (0.1 to 0.16 inch) long with a rounded dorsal keel and short beak.

Figure 4.2.2.10.—*Stuckenia pectinatus* (L.) Boerner. (Photograph courtesy of Linda Hurley, U.S. Fish and Wildlife Service).

Ecology. *Stuckenia pectinatus* grows in fresh, alkaline, brackish, or saline waters of lakes, ponds, rivers, streams, irrigation canals, and coastal marshes. Sago pondweed reproduces by seed and vegetatively by rhizome growth and from bulblets (tubers). These tubers are utilized by waterfowl as a food source.

4.2.2.10.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal.

Cultural or Environmental Control. Reservoir drawdown; liners, shading, benthic, and bottom barriers.

Biological Control. Triploid grass carp.

Chemical Control. Copper complexes, xylene, acrolein, endothall, fluridone, diquat dibromide, 2,4-D.

4.2.2.11 Water stargrass (Heteranthera dubia)

Identification. Water stargrass is widespread in the Midwestern and Southeastern States but is not commonly seen in western irrigation canals. It has been reported most extensively in canals of Arizona and occasionally in California. Where found, it is a weed pest that is not as serious as filamentous green algae.
The leaf and stem tissue of the submersed plants could be mistaken for pondweed species were it not for the yellow star-like flower. The flowers are produced singularly on elongated, tube-like stems that are exposed above the water surface. The water stargrass leaves lack a midrib vein and are grass-like with bases attached directly to the branching stems. The leaf sheaths are thin, membranous, and tipped with small pointed appendages.

Figure 4.2.2.11.—*Heteranthera dubia* (Amy Johnson, Arkansas Native Plant Society).

Ecology. A form of this plant produces shorter leaves and stems and grows on shallow mud bars. This form is reported to flower more often than the submersed aquatic type. The genus *Heteranthera* is sometimes commonly referred to as mud plantain.

4.2.2.11.1 Control methods

Mechanical or Physical Control. Chaining, excavation, hand cutting, hand pulling, dredging, harvesting, sediment removal. Dredging (aqua mogs); total acreage removed depends on various factors.

Cultural or Environmental Control. Reservoir drawdown; long-term desiccation for best results.

Chemical Control. Endothall, diquat dibromide, 2,4-D.

4.2.3 Floating aquatic weeds

4.2.3.1 Giant salvinia (Salvinia molesta)

Identification. A floating aquatic fern, native to southeastern Brazil. An individual plantlet consists of a horizontal stem that produces two floating leaves (fronds) up to 25 mm (1 inch) long and highly dissected submerged fronds up to 25 cm (10 inches) long. The floating leaves are green, sessile to short petiolate, broadly ovate in shape with entire margins. The upper surface of the floating fronds is covered with parallel rows of hairs that have a characteristic “cage-like” structure at the apex. The floating leaves become crowded and fold against one another, resulting in a more vertical leaf position as the plant ages.

Ecology. Introduction is thought to have arisen from the water gardening and/or aquarium trade, where plants are either sold directly or occur as contaminants in water garden stocks. Expected to be found in lakes, ponds, slow moving streams, canals, and ditches in central and southern California, as well as the Southern United States, giant salvinia is expected to naturalize wherever water hyacinth persists or in areas that experience frost without the formation of ice on the freshwater surface.

Giant salvinia can impact irrigation systems, navigable waters, fisheries, and electric power production. Dense mats of giant salvinia reduce light penetration and result in oxygen depletions. Oxygen depletion may be so severely reduced below a mat that it influences fish survival. Extensive mats may exacerbate a situation by preventing water circulation and mixing.

Figure 4.2.3.1.—*Salvinia molesta*. (Photo by Vic Ramey, University of Florida/IFAS Center for Aquatic and Invasive Plants. Used with permission).

4.2.3.1.1 Control methods

Mechanical or Physical Control. Excavation, booms, skimmer, netting, hand picking.

Biological Control. Triploid grass carp, *Cyrtobagous salviniae* - weevil.

Chemical Control. Copper complexes, glyphosate, fluridone, diquat dibromide, 2,4-D.

4.2.3.2 Common duckweed (Lemna spp.)

Identification. The *Lemnaceae* are the structurally simplest of the flowering plants. The plants are not differentiated into stems and leaves but form an undifferentiated leaf-like body referred to as a frond or thallus. The plant consists of leaf-like structures and a variable number of roots, which are key characteristics for identification. *Lemna minor* is the smallest of the genus, about the size of a pinhead. Plants of the *Wolffia* genus have fronds smaller to those of *Lemna* and are microscopic.

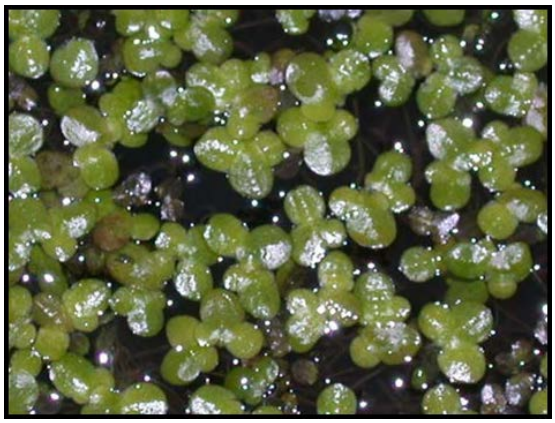

Figure 4.2.3.2.—*Lemna* species. (Photograph courtesy of Rene Reyes, Mid-Pacific Regional Office, Reclamation.)

Ecology. This family has four genera of which *Lemna* is probably most often seen on irrigation systems where there is static water. During warm summer months, these plants can cover the surface of a pond in a few weeks. The plant overwinters both by seed and vegetatively by a minute bulblet that sinks to the bottom of the water body and rises to the surface the following season.

Common duckweed is a widely dispersed floating aquatic weed in western water systems. It often is found in slow-moving or static waters. It becomes a pest in irrigation systems, where it is carried into siphons, trashracks, and pump inlet structures.

4.2.3.2.1 Control methods

Mechanical or Physical Control. Harvesters, hand weed screens.

Biological Control. Triploid grass carp.

Chemical Control. Copper complexes, fluridone, diquat dibromide, 2,4-D, triclopyr.

4.2.3.3 Water hyacinth (Eichornia crassippes)

Identification. Its attractive blue- purple flower and characteristic bulbous leaf stem with rounded leaf blade make it an easy plant to identify. The individual plants consist of several leaves in rosettes that are connected by stolons. The leaf petiole is usually inflated, spongy, and up to 20 cm (8 inches) long. The leaf blades are thickened, leathery, 2 to 15 cm (1 to 6 inches) long and 2 to 20 cm (1 to 4 inches) wide. The capsule-like fruit contains many seeds that provide for extensive spread of the species in suitable climates. During periods of growth,

water hyacinth can survive as seeds that remain dormant until reflooding occurs. Because water hyacinth is free floating, water currents and wind can distribute plants within a water body.

Figure 4.2.3.3.—*Eichornia crassippes* Mart. (Photograph courtesy of Rene Rayes, Mid-Pacific Regional Office, Reclamation.).

Ecology. A native to South America, first introduced into the United States in 1884 as an ornamental. Water hyacinth is an aquatic pest in many areas of the United States, primarily in the Southeast. The weed may also be found in western water projects in the Central Valley of California and projects in the Southwest. It also occurs in the upper river channels feeding into the San Joaquin River channel. Increases in flow can flush water hyacinth downriver where they pile up against floating booms, trashracks, and fish screens, and also plug marinas and harbors. Mechanical means are used to remove the water hyacinth at considerable time and expense.

4.2.3.3.1 Control methods

Mechanical or Physical Control. Excavation, flail chopper, hand picking, harvesters, rotovation.

Biological Control. *Neochetina bruchi* - weevil, *Neochetina eichhorniae* - weevil, *Niphograpta abiguttalis* – moth.

Chemical Control. Copper complexes, diquat dibromide, 2,4-D, triclopyr.

4.2.4 Emersed aquatic weeds

4.2.4.1 Cattails (Typha spp.)

Identification. The two species most commonly observed are *T. latifolia*, the common or broadleaf cattail, and *T. angustifolia*, the narrowleaf cattail. *Typha* species are quite easily recognized by their growth of stout jointless stems, linear

flat leaves, and cylindrical flower spikes. Leaves are nonlinear, glabrous, arranged in two ranks on opposite sides of the stem and in two vertical ranks, not differentiated into petiole and blade.

Identification is readily accomplished by study of the flower spikes (consisting of unisexual densely crowded flowers in terminal elongated cylindrical spikes), which consist of two portions: the female or pistillate portion of the spike is below, and the male or staminate portion is above. Each flower spike will produce hundreds of seeds that are disseminated by air and water over wide areas to spread the species. These plants produce underground stems or rhizomes, which serve as food storage organs, having high starch content. Aquatic animals, such as muskrats, readily eat the rhizomes.

Figure 4.2.4.1.—Cattail, *Typha latifolia*. (Photograph courtesy of Rene Reyes, Mid-Pacific Regional Office, Reclamation).

Ecology. Cattails are the most common perennial emersed aquatic weed pest in the Western States, and all species of *Typha* in the United States are native. Cattails are found in most western irrigation systems and are especially troublesome in drains and slow-moving water in shallow channels. They can spread throughout a drain in a short time, reducing the capacity of drainage channels.

4.2.4.1.1 Control methods

Mechanical or Physical Control. Excavation, flail chopper, hand cutter, cookie cutter.

Biological Control. Triploid grass carp.

Chemical Control. Glyphosate, fluridone, diquat dibromide, 2,4-D, triclopyr.

4.2.4.2 Bulrush (Schoenoplectus and bolboshoenus spp.)

Identification. Bulrushes belong to the sedge family, *Cyperaceae*, which are grass- like or rush-like herbs, generally perennial or rarely annual. They spread vegetatively and overwinter by means of scaly, stout, reddish horizontal stems or rhizomes. These plants are characterized by cylindrical or variously angled erect stems called culms and much smaller leaves that develop near the plant base. Leaves are often overlooked because of their small size and clasping nature in some species.

Figure 4.2.4.2.—*Schoenoplectus lacustris* (Bernd Haynold, https://en.wikipedia.org/wiki/Bulrush).

Ecology. Common in irrigation projects in the West, especially in marshy areas or in shallow drains. Bulrush habitat is similar to that of cattails, and they contribute extensively to the marshy vegetation complex that restricts drainage channel capacity.

4.2.4.2.1 Control methods

Mechanical or Physical Control. Excavation, flail chopper, hand cutter, cookie cutter.

Biological Control. Triploid grass carp.

Chemical Control. 2,4-D.

4.2.4.3 Alligatorweed (Alternanthera philoxeroides)

Identification. A spreading aquatic weed that forms extensive floating mats. Stems become hollow and slightly flattened with age, often pink when fresh. The linear leaves develop on the stems in an opposite arrangement, with smooth or entire margins, and are somewhat waxy in appearance. One leaf joins with the opposite leaf to form a narrow sheath. The inflorescence is a several-flowered whitish head on a stalk.

Petals are lacking, and sepals are whitish. The creeping branches, prostrate stems often jointed, and roots form extensively at stem joints. Stems may be several yards long and extend from the shoreline into shallow water. Alligatorweed in the United States has not been observed to produce viable seed; all reproduction is vegetative.

Figure 4.2.4.3.—*Alternanthera philoxeroides* (Chris Evans, University of Illinois).

Ecology. Native to South America and introduced into the United States around 1900, Alligatorweed is mostly a problematic pest in the Southeast. Dense mats may impede flow in irrigation canals, restrict small boat navigation, and hinder fishing and other forms of recreation.

4.2.4.3.1 Control methods

Mechanical or Physical Control. Excavation, flail chopper, hand removal, harvesting, rotovation.

Biological Control. *Agasicles hygrophila* - flea beetle, *Amynothrips andersoni* - thrips, *Vogtia malloi* - stem borer.

Chemical Control. Glyphosate, fluridone, triclopyr.

4.2.4.4 Flowering rush (Butomus umbellatus)

Identification. A tall perennial plant that can grow as either an emersed or submersed form. It has sword-shaped leaves with a triangular cross-section and a low, horizontal stem. It blooms from July to September. The flower stalks are umbrella-shaped clusters of white to pink three-petal flowers. Plants grow up to 1.5 m high with leaves up to 1 m long. Flowers are approximately 2-3 cm across.

Figure 4.2.4.4.—*Butomus umbellatus* (Invasive Species Council of British Columbia).

Ecology. Intentionally brought to North America from Europe as an ornamental plant, flowering rush has escaped to waterways from garden plantings or by boats and recreational equipment through vegetative fragmentation. Fragmented rhizomes and bulbils can travel long distances and regrow. Flowering rush is most often found shallow water but can grow in a submerged form at greater depths. Rodents also use parts of the plant and can contribute to its spread.

4.2.4.4.1 Control methods

Mechanical or Physical Control. Hand digging (can regrow from root fragments).

Cultural or Environmental. Inspection of boats. Protect healthy native wetlands.

Chemical Control. Diquat dibromide, imazapyr.

4.2.4.5 Hairy willow-herb (Epilobium hirsutum)

Identification. Perennial semi-aquatic plant covered in soft hairs. Flowers are bright pink with 4 notched petals. Leaves mostly opposite, with serrated edges and attach directly to the stem. Seeds are wind dispersed and have a tuft of long white hair on the end.

Figure 4.2.4.5.—*Epilobium hirsutum*. (King County, WA, Noxious Weed Control Program).

Ecology. Typically grows in water-logged soils and easily tolerates inundation. Infestations can degrade natural habitat and impede the flow of water. Hairy willow-herb was likely introduced as an ornamental planting. It will readily spread into undisturbed areas and form dense stands. Flowers in July-August; seeds may remain viable in the soil for several years.

4.2.4.5.1 Control methods

Mechanical or Physical Control. Hand digging (can regrow from root fragments).

Chemical Control. Glyphosate, imazapyr.

4.2.4.6 Yellow-flag iris (Iris pseudacorus)

Identification. Perennial, aquatic plant that can grow 2-3 ft tall in shallow water. Flowers are yellow, with brownish purple markings, while leaves are long and sword-shaped. The leaves and rhizomes produce resins that can cause skin irritation.

Ecology. Grows in riparian areas and along the shores of lakes, usually in shallow water or mud. It forms large clumps that are connected through rhizomes. Rhizome fragments or seeds can establish new colonies.

Figure 4.2.4.6.—*Iris pseudacorus*. (Tualatin Soil and Water Conservation District, OR).

4.2.4.6.1 Control methods

Mechanical or Physical Control. Hand digging (can regrow from rhizome fragments).

Cultural or Environmental. Do not burn, it will cause seeds and rhizomes to sprout.

Chemical Control. Glyphosate, imazapyr.

4.2.5 True mosses

True mosses, of the plant division Bryophyta, are predominantly land plants. They are one of the simplest types of green terrestrial plants. A few species are aquatic or semi-aquatic in growth characteristics and vary in size.

The conspicuous plant, or gametophyte of commonly observed mosses, is differentiated into an erect central axil or stem with spirally arranged leaves resembling those of true flowering plants. Generally, true mosses produce short stems only a fraction of an inch in length that rise from dense mats of growth.

Occasionally, true mosses are found growing on small areas of canal linings, often in shaded areas, where a thin soil substrate is available. They can cause problems in water distribution systems. Two genera, *Fontinalis* (one of the largest mosses) and *Fissadens* (one of the smallest) are found most often in western water systems. Many other species probably grow in various widely scattered western irrigation systems but have not been reported. Dense mats of true mosses along a concrete-lined canal can significantly reduce water- carrying capacity.

4.2.5.1.1 Control methods

Mechanical or Physical Control. Rotary brush removal after chemical desiccation. Labor intensive.

Cultural or Environmental. Reservoir drawdown; long-term desiccation for best results.

Chemical Control. Scythe.

4.2.6 Terrestrial herbaceous weeds

Terrestrial weeds are grouped by similarities in habitats, physiology, and management strategy.

4.2.6.1 Common reed (Phragmites australis), Giant reed (Arundo donax), Reed canarygrass (Phalaris arundinacea)

Identification. *Phragmites* is usually about 1.5 to 2.4 m (5 to 8 ft) tall but can grow to 3.6 m (12 ft). Stem diameter is about 1.3 cm (0.5 inch) or less, and leaves are 2.5 cm (1 inch) or less wide at the base. Flowers are borne in an open, spreading, plume-like inflorescence from the top of the plant. Phragmites can produce viable seed, but most stands enlarge by vegetative reproduction from the rhizomes.

Giant reed is among the largest of the grass species, growing as tall as 7.6 m (25 ft). This native of Asia was introduced to the United States for erosion control and building materials, and it is the source of the reed in many woodwind musical instruments. The hollow stems up to 3.8 cm (1.5 inches) in diameter are divided by partitions at the nodes like bamboo. *Arundo* does produce a plume-like inflorescence, but seeds produced by *Arundo i*n the United States are seldom, if ever fertile. Plants reproduce vegetatively through stem nodes and rhizomes, and infestations usually spread downstream. Often mistaken as “bamboo”.

Reed canarygrass has stems 0.6 to 2.1 m (2 to 7 ft) tall that are covered with a waxy coating that gives it a blue-green color. Leaf blades are flat, and 0.6 to 2 cm (0.25 to 0.75 inch) wide. Its inflorescence does not have a plume shape. This perennial, cool-season grass spreads by seed and rhizome. Reed canarygrass is found throughout most of the United States and is considered native to North America, but European cultivars have been introduced and are known to hybridize. In many areas of the country, it is cultivated as an important hay, silage, or pasture forage plant.

Figure 4.2.6.1.—*Arundo donax* (Joseph DiTomaso, California Invasive Plant Council).

Ecology. These aggressive perennials, all members of the grass family, can be found along streams and in marshes in all of the Western States. They create serious management problems when growing in canals and irrigation ditches by physically blocking water transport, catching sediment and trash to further block water, expanding the potential flood plain, and increasing fire danger. In some cases, the large roots and rhizomes grow underneath concrete linings, breaking the linings of irrigation and drainage channels.

Common reed has both native and non-native strains that are known to hybridize. This plant has been a component of wetlands in the United States for thousands of years, but in the past century has become a dominant invasive from both genetic and environmental causes. Plants can appear similar to *Arundo*, with *Arundo* being generally larger, though there is some overlap and response to growing conditions. It is best to consult an expert if in doubt because there are finer details that can differentiate the two.

4.2.6.1.1 Control methods

Mechanical or Physical Control. Cutting can be used to manage small infestations. Recommendations for *Phalaris* call for at least five cuttings over the growing season. For *Phragmites* and *Arundo,* it is cautioned that cutting these grasses several times per season or at the wrong time will increase stand density. Cut these two species just before the end of July, which will remove most of the food reserves before they can be stored in the rhizomes. This must be repeated for several years to see any appreciable results. It is important to remove all debris to a dry area for an extended period of time to prevent rerooting. *Arundo* has been found to resprout from stems dried for 123 days and from chipped stem pieces as small as 2 cm (0.75 inch).

Reed canarygrass can be burned in the late spring or late fall. This should only be done where a seed bank of fire-adapted natives exists for recolonization. Common and giant reed are not affected by fire, because it rarely damages the rhizomes. Burning can be used to remove dead vegetation after chemical treatments to allow desirable species to germinate.

Cultural or Environmental Control. In areas where water level control is possible, flooding can be used to manage common reed by covering the rhizome with 1 m (3 ft) of water for at least 4 months during the growing season.
Biological Control. Biological controls are not currently available for these species, although investigations are being conducted.

Chemical Control. All three species can be treated effectively with glyphosate. Reed canarygrass should be sprayed in the spring. Common and giant reed must be treated when plants are actively growing and only at mid to full bloom. Better results are achieved with aerial application than hand-held equipment, because difficulty of access makes it hard to get good coverage otherwise. Retreatment is needed for missed plants or plants that were not affected because they were not blooming at the time of treatment. Glyphosate has also been used to treat cut stems of giant reed at full bloom. It is applied to the cut surface using a wiper within 5 minutes of cutting.

4.2.6.2 Cheatgrass (Bbromus tectorum), Medusahead (Taeniatherum/eelymus caput-medusae)

Identification. Cheatgrass is a winter annual, germinating in the fall and growing quickly in the early spring. It reproduces only by seed. A mature, seed-producing plant can range in height from 5.0 cm (2 inches) to about 0.6 m (2 ft) tall. The flat leaf blades are densely covered with soft hairs and feel downy to the touch when plants are green. The large, open inflorescence appears to droop over to one side. Seedheads and leaves turn from green to reddish-purple at maturity, then tan by the end of June as it dies and dries.

Cheatgrass has finely divided fibrous roots, mostly in the top 30 cm (12 inches) of soil. These shallow roots allow it to outcompete desirable perennial grasses for moisture, especially because it begins growing so early in the season. As a stand of cheatgrass expands, the uniform supply of dry fuel during the peak summer fire season causes further changes in vegetation. Fires start and spread quickly in dry cheatgrass every 3 to 10 years on average. Native vegetation has adapted to a fire interval of 50 to 100 years and cannot recover in the short intervals between fires in cheatgrass-dominated areas, so a larger cheatgrass monoculture results.

Medusahead is an aggressive winter annual, up to 0.6 m (2 ft) tall, and reproduces by seed. Leaf blades appear rolled, generally 3.18 mm (0.125 inches) wide or less. The seedhead resembles a spike of grain with very long bristles that makes it nearly as wide as it is long. These stiff bristles can be 2.5 to 10.2 cm (1 to 4

inches) long, and the longer ones feel barbed if rubbed in the right direction. At first the bristles are straight, but as the seedhead matures and the plant turns from green to purple to tan, they become very twisted. Medusahead can be confused with foxtail barley or squirreltail, but its seedhead spike does not break apart as seeds fall. Instead, the seeds fall off and leave a bristly head that persists over winter

Figure 4.2.6.2.—*Bromus tectorum* (Chris Evans, River to River CWMA, Bugwood.org).

Ecology. These aggressive grasses can invade undisturbed areas, but they are most likely to be found where the vegetation has been disturbed or degraded by cultivation, grazing, or fire. Cheatgrass is established widely across the United States; the range of medusahead is more limited but is expanding.

Medusahead's roots enable it to displace most other vegetation, even cheatgrass. Some roots extend as deep as 102 cm (40 inches) and allow it to deplete deep as well as shallow moisture. Coarse foliage and low palatability from high silica content provides medusahead with additional selective advantages. The silica also makes dead foliage slow to decompose and leads to a buildup of a dense, long-lasting litter layer 5 to 10 cm (2 to 4 inches) thick, which burns readily.

The plants self-pollinate, and seed production is very high. About 95 percent of the seed can germinate after autumn rains, and germination can take place at temperatures as low as 0 °C (32 °F). Cheatgrass seed is usually viable for only about 1 year under actual field conditions and cannot emerge if buried deeper than about 6 cm (2.5 inches). The sharp-pointed seeds readily penetrate fur and clothing for wide dispersal. Cheatgrass is readily grazed when green and growing, but the dry foliage and sharp, injurious seeds after June leave cattle and wildlife with few resources.

Medusahead seeds are viable for at least 3 years and are widely dispersed by attaching to animals or clothing.

4.2.6.2.1 Control methods

Mechanical or Physical Control. Spring plowing and disking have been found to give good control for medusahead where it is practical and combined with other treatments. Mowing and disking are not considered good control methods for cheatgrass. Mowing must be repeated frequently, is very labor intensive, and plants soon adapt to produce seed at heights below the cutting height. Disking must bury seed 10 to 15 cm (4 to 6 inches) deep to prevent germination and must be repeated. This disturbs any remaining or planted desirable species. Hand pulling of small infestations of cheatgrass before seed set can be effective in small infestations, but the program must be continued for several years until the seed bank is exhausted.

Prescribed burns can be dangerous to conduct, as fires in the dry grass can easily overrun personnel and equipment. Some seed usually survives in unburned litter, and the fires cause damage to desirable plants that are not as adapted to fire as cheatgrass. Unless an area is reseeded with competitive grasses, cheatgrass density generally increases after fire.

Green stripping with desirable species can provide firebreaks in large cheatgrass infestations.

Burning can be a useful practice in medusahead control to eliminate the litter layer, which otherwise is very slow to break down. Burning when seed still has high moisture content can reduce stands if a slow fire develops. Burning should be used with mechanical or chemical treatments and followed with revegetation.

Cultural or Environmental Control. Grazing medusahead is not practical, as the grass is unpalatable to livestock, and they prefer to eat the other available plant species. Cheatgrass is palatable in the springtime, so managed grazing can be used, but it is not a recommended method of control. This method is very ineffective if the only grass available is cheatgrass and no competition results from other grasses. It is difficult to totally prevent seed production by grazing because of the ability of cheatgrass to regrow and produce seed on small plants. Seeds that are produced can cause physical damage to the face, mouth, and intestinal tract of grazing livestock.

Biological Control. Biological controls are not available for these species. The use of soil bacteria from the genus Pseudomonas to impact the germination and growth of cheatgrass is being investigated. Research is proposed to evaluate fungal pathogens for the control of medusahead.

Chemical Control. Chemical control must be repeated for 2 to 5 consecutive years and includes revegetation activities to be effective. Some chemicals found to work against cheatgrass are paraquat, glyphosate, atrazine, and sulfometuron. Chemical control of cheatgrass and medusahead is similar. Timing and rate of

application are important so as to affect any remaining perennial grasses or dicots as little as possible. Pre-emergent herbicides can be very effective if applied in the fall, while cheatgrass is growing but perennial grasses are dormant.

Application of herbicides in the spring should take place before perennial grasses begin to grow. Herbicides applied after this period can still be very effective against cheatgrass but will impact other plants. Paraquat and glyphosate may be applied following label direction when 50 percent of the cheatgrass is in full seedhead, but before it begins to turn red (ripe seed). It is important to realize that all vegetation will die after application, but most perennial grasses will quickly come back from the roots. For large areas, aerial application is preferable because rough ground often causes skipping when applied with a land vehicle.

Revegetation and Competition. Revegetation is an essential step in recovering land from cheatgrass or medusahead. It may be better to reseed with competitive species first, then work in native species after the annual grass has been suppressed several years. The best plants to use are cool-season, competitive, perennial grasses that are adapted to grow with the amount of moisture available. It is sometimes difficult to establish grasses in areas receiving less than 30 cm (12 inches) of annual precipitation, but drought-resistant species such as Hycrest crested wheatgrass and Siberian wheatgrass can be tried. Where annual precipitation is 30 to 41 cm (12 to 16 inches), good species are Hycrest crested wheatgrass, Sodar streambank wheatgrass, and Luna pubescent wheatgrass.

Regar meadow bromegrass and orchardgrass are competitive where annual precipitation exceeds 41 cm (16 inches). Other grasses for non-dryland sites include Bozorsky Russian wildrye, native Western wheatgrass, and covar sheep fescue.

4.2.6.3 Bull thistle (Cirsium vulgare), Musk thistle (Carduus nutans), Scotch thistle (Onopordum acanthium)

Identification. These thistles are generally biennial, have a fleshy taproot, and reproduce only by seeds. Their bright purple flower heads, produced after the rosette bolts in their second year, are 3.8 to 7.6 cm (1.5 to 3 inch) in diameter. Leaves are deeply lobed and spiny, and the stems have a winged appearance. They are all large plants at maturity under favorable growing conditions, with bull thistle reaching heights of 1.5 m (5 ft), musk thistle to 1.8 m (6 ft), and Scotch thistle as tall as 2.4 m (8 ft) with a 1.5-m (5-ft) spread.

Figure 4.2.6.3.—*Cirsium vulgare*. (Photograph courtesy of National Park Service.).

Ecology. Native to Europe and Asia, they are all widely distributed in the Western United States. They easily invade disturbed or degraded sites in pastures, fields, and along roadways. Scotch thistle will occupy dry sites, but it is frequently associated with waterways and areas of high soil moisture.

These thistle species spread entirely by seeds, and seed production per plant is high. Most seed falls within a few yards of the plant, but dispersal by vehicles, equipment, animals, wind, and water is possible. Bull thistle averages 100 seeds per flowerhead and 5,000 seeds per plant. About 90 percent of these seeds germinate within a year, but seeds can remain viable in the soil for 5 years. Each musk thistle plant can produce 10,000 seeds, but only about a third of these are viable. These seeds can survive 10 to 15 years in the soil. Scotch thistle plants produce about 120 seeds per flowerhead. These seeds are viable for 6 years in the soil, but they need high soil moisture to germinate.

4.2.6.3.1 Control methods

Mechanical or Physical Control. These biennial thistles do not tolerate tillage. Tillage, hoeing, or hand pulling can be successful. It is necessary to sever the root below ground level to remove all buds. According to some reports, a plant may be able to regrow if this is done before the plant is fully bolted.

Mowing can reduce seed output if done when the terminal head is in late-flowering stage and all mowed debris is gathered and burned. However, if mowing can be done within 2 days of when the terminal flowerbud opens, viable seed will not be produced.

Cultural or Environmental Control. Thistles are spiny plants even from the early stages of their growth, and unpleasant to handle, let alone graze. Although horses and cattle will occasionally nibble thistle (especially in extreme drought

conditions), livestock generally avoid infested areas. However, good grazing management can prevent the establishment of thistles by preventing the establishment of overgrazed areas which are a prime location for infestations.

Biological Control. Methods of biocontrol using plant diseases or insects do not give complete control of any thistle infestation and should be combined with cultural or chemical controls. Insects used for biocontrol include:

- Bull thistle. Bull thistle gall fly, *Urophora stylata* Fabricius. The larvae disrupt seed formation by causing galls in the seedhead. They have not provided good control to date, as populations have not been stable, and the best results so far have been reductions in seed production of up to 60 percent. The insects listed below for musk thistle will also attack bull thistle.

- Musk thistle. Thistle head weevil, *Rhinocyllus conicus* Frölich. The larvae disrupt seed production by feeding on the developing seeds and surrounding tissue. This weevil feeds on a number of noxious and native thistles, so introductions should be made cautiously. It does not destroy 100 percent of the seeds produced by a plant, mostly because its life cycle is not synchronized to the plant's ability to produce flowers over an extended period of time.

- Thistle crown weevil, *Trichosirocalus horridus* Panzer. The larvae feed on the growing points of the rosette and stems, reducing plant vigor and flowering. This weevil is most effective when used in conjunction with *R. conicus*.

- Scotch thistle. No biocontrol agents are released in the United States specifically against Scotch thistle. Some strains of *R. conicus* will attack it, as will *T. horridus*.

Chemical Control. Weather and growth stage of the thistle influence the effectiveness of chemical control. Tolerance to most herbicides increases after the plant bolts and increases further as the plant begins to flower. Herbicides that have some activity after bolting include chlorsulfuron and metsulfuron. A surfactant must be used with these to see any effect, and the latest time to apply is when terminal flowers have opened to the size of a dime. When plants are in the rosette stage, effective herbicides include clopyralid, dicamba, picloram, and 2,4-D. Cool (below 10 °C; 50 °F) or dry conditions decrease the effectiveness of 2,4-D and dicamba, so these two are used on rosettes more often in the spring than fall.

4.2.6.4 Canada thistle (Cirsium arvense)

Canada thistle is a perennial plant that reproduces both vegetatively from a creeping horizontal root stock and by seeds. A mature plant can stand 1.21 m (4 ft) tall, with deeply lobed, spiny leaves and clusters of pinkish-purple flowerheads that are 1.3 to 2 cm (0.5 to 0.75 inch) diameter. Each plant generally will produce only either male flowers or female flowers (which have a vanilla-like scent). Roots can extend 4.6 m (15 ft) horizontally and from 0.06 to 6.7 m (2 to 22 ft) deep. The horizontal roots give rise to adventitious shoots of the same sex as the parent plant.

Figure 4.2.6.4.—*Cirsium arvense*. (Photo credit: Tim Higgs, July 2004, Grand County (Utah) Weed Department).

Seed production depends on the proximity of plants of both sexes for pollination and varies greatly. On average, one female plant will produce 1,000 seeds. These seeds can remain viable in the soil for up to 22 years, with those buried more than 20 cm (8 inches) deep surviving the longest. Seeds buried up to 7.6 cm (3 inches) deep can remain viable for as long as 5 years. Seeds have poor dispersal by wind but their ability to float leads to this plant being a familiar one along ditchbanks and streams. Equipment, animals, or contaminated crop seed and hay can also disperse seeds or root and stem fragments.

Canada thistle is found in every Western State and does best where annual precipitation is 41 to 76 cm (16 to 30 inches), or where soil moisture is adequate. It is not found in deeply shaded sites. It has the ability to grow in many different habitats and can invade undisturbed sites.

4.2.6.4.1 Control methods

Mechanical or Physical Control. Cultivation can be an effective method of control if repeated regularly. Repeated cultivation at 21-day intervals over a 122-day period eradicated mild infestations in Idaho. Early work demonstrated that hoeing "as soon as shoots appear above ground" would eventually kill the plants. These studies emphasized the importance of eliminating all shoots at cultivation to prevent carbohydrate storage in the root system. Repeated mowing in alfalfa fields has given good control, probably because of competition from the alfalfa. In a recent study, mowing two or three times consistently enhanced Canada thistle control following applications of picloram, picloram + 2,4-D, clopyralid + 2,4-D, and dicamba.

Biological Control. Biological control does not give complete control of Canada thistle infestations. It must be combined with cultural or chemical controls.

Small infestations should be eliminated entirely by other means. In addition to the insects listed below; those affecting musk thistle will also attack Canada thistle (*Rhinocyllus conicus* Frölich, *Trichosirocalus horridus* Panzer).

- Canada thistle stem weevil, Ceutorhynchus litura Fabricius. The larvae mine tissues of the leaf, stem, and root. Important secondary damage is caused by other insects and pathogens entering through holes made by the larvae.

- Canada thistle bud weevil, Larinus planus Fabricius. This insect was accidentally introduced and is not as host-specific as most biocontrol agents. It should be used with caution. The larvae reduce seed production by feeding on seeds and surrounding tissues. Canada thistle reproduces mostly by vegetative spread of the roots, so reduction of seed output is not of the greatest importance.

- Thistle stem gall fly, Urophora cardui L. The larvae redirect the plant's energies to forming a large gall in the stem. Sometimes this can stop flowering, but it does not kill the plant. As the plant reproduces mostly vegetatively, this is not an important control.

Chemical Control. Reviews of chemical control show that single herbicide applications do not provide long-term control, due to the difficulty in killing the root system, which can survive even though the shoots have been killed. Effective chemical control requires multiple applications. Herbicides used for Canada thistle control in rangelands include 2,4-D, dicamba, clopyralid, metsulfuron, 2-methyl-4-chlorophenoxyacetic acid and its sodium salt, esters and organic amines (MCPA), glyphosate, and picloram.

- 2,4-D can control Canada thistle when applied before bud stage. The effectiveness of 2,4-D declines greatly as the plant begins to bloom. The short residual life of this herbicide makes it a good choice if grass is to be seeded after herbicide application.

- Dicamba can be applied at any time to actively growing plants but is most effective in controlling Canada thistle when applied at the late vegetative to bud stage or in the fall if there is 20 to 30 cm (8 to12 inches) of regrowth. Established grass growing under stress is susceptible to dicamba injury.

- Clopyralid herbicides should be applied when Canada thistle is actively growing. Higher rates are needed for dense infestations or application under poor growing conditions, such as drought. Lower rates can be used when the plant is in the rosette to prebud stage. Clopyralid should not be used on newly seeded areas until the grass is well established, and it may cause damage to desirable broadleaf forage plants.

- Several studies have demonstrated effective Canada thistle control for 1 year or more with higher label rates of picloram. Lower rates of picloram used in conjunction with 2,4-D will also give control.

- Glyphosate should be applied when the plants are at or beyond the bud growth stage. Since it is nonselective, care must be taken to avoid eliminating surrounding desirable vegetation.

4.2.6.5 Russian thistle (Salsola spp.)

Identification. The seedling of the plant resembles a very young pine tree seedling and is the most vulnerable stage of the plant. The wind-pollinated flowers in the axils of the sharp, spiny leaves are inconspicuous, and the pollen itself is a potent allergen. Russian thistle taxonomy is complex, and several species are contained within the group (*Salsola kali* L., *S. australis* R. Br., and *S. pestifer* A. Nels.). The Russian thistle is not a true thistle; it is in the Goosefoot family, not the Sunflower family, as are the other thistles.

Ecology. This bushy annual plant arrived from Russia in the 1870s and quickly caused problems with dryland small-grain production in many areas of the West. Special cells at the bottom of the stem allow the plants to break off and become a “tumbleweed” to disperse its seeds. One plant can produce about 100,000 seeds, but seed viability drops to nearly zero after 2 years.

This plant is a problem in irrigation districts when the tumbleweeds accumulate in irrigation ditches and along fence lines.

Figure 4.2.6.5.—*Salsola* spp. (UC Statewide IPM Program).

4.2.6.5.1 Control methods

Mechanical or Physical Control. Mowing or cultivation of young plants under 6 cm (2.5 inches) tall may provide control. When used on older plants before seed set, this can reduce infestations, but it must be repeated yearly until all seed reserves are exhausted.

Biological Control. Moths have been tried as biocontrol agents for Russian thistle, but they were found to have little or no impact on the weed populations. No working biocontrol agents are currently available.

Chemical Control. Some plants have been found to be resistant to Aceto Lactate Synthase-inhibitor herbicides (especially sulfonylurea herbicides such as chlorsulfuron and triasulfuron), and resistance to the triazine herbicides has also been observed.

A nonselective, broadleaf herbicide such as glyphosate can provide control of Russian thistle when applied before seed set. Use of 2,4-D may cause Russian thistle to become tough and leathery, producing a plant that is more difficult to manage.

4.2.6.6 Yellow starthistle (Centaurea solstitialis)

Identification. This blue-green to gray-green plant has a vigorous taproot and ranges in height from 15 cm to 1.5 m (6 in to 5 ft). Stems and leaves are covered with small hairs that give them a white appearance, and the stems may appear flattened and “winged.” The most easily recognized feature is the yellow dandelion-like flower with sharp spines at the base.

Figure 4.2.6.6.—*Centaurea solstitialis*. (Photo credit: Preston Higgs, July 2007).

Ecology. Yellow starthistle is a winter annual from the Mediterranean region that arrived on the west coast in the early 1800s. It reproduces only by seed, with the number of seeds produced per plant varies from 700 to 10,000, depending on plant density and precipitation. Most of the seed will germinate during autumn rains, but about 10 percent will remain viable in the soil for up to 10 years. More than 90 percent of the seeds fall within 0.6 m (2 ft) of the parent plant, but long-range dispersal by wind, birds, and vehicles does occur.

4.2.6.6.1 Control methods

Mechanical or Physical Control. Repeated hand pulling of this annual plant can be effective if it is done before flowering and most of the root is removed.

Cultivation or hoeing in the fall after germination can kill many seedlings, but more will germinate after subsequent rains. This will help reduce the seed bank. Cultivation in the spring would not have to be repeated that year but would need to be deeper to affect the taproot.

For mowing to be a good control, it must be timed properly. Mowing too early or too late will either encourage regrowth or aid in seed dispersal. Mowing should only be done when about 2 to 5 percent of the flowers begin to bloom. It may need to be repeated 4 to 6 weeks later, if the plants are able to produce more flowers.

There is disagreement about the effectiveness of burning in controlling yellow starthistle. Some authorities believe burning can result in increased plant size and seed production by releasing nutrients tied up in plant material. Others have had success in reducing infestations by burning. This burning is conducted when plants are green and have not produced seed, so there must be enough dry biomass from other plants or from mowing to carry the fire.

Cultural or Environmental Control. Grazing and proper grazing management can be used to control or prevent yellow starthistle invasion. It is very important not to allow horses to graze on yellow starthistle, as it can lead to a fatal nervous disorder called "chewings disease." Cattle and sheep can graze it before the sharp spines develop with no ill effects. Proper timing and repeated grazing is necessary.

Establishment of grasses is necessary after control to prevent reinfestation, but grasses can also be used to compete with yellow starthistle and reduce an infestation. Additional methods of control must be used in conjunction with this method, especially in the early years. Choose desirable species that are very competitive under site conditions. There has been success with legumes and both cool-season and warm-season perennial grasses when managed properly.

Biological Control. A number of insect biocontrols have been introduced and are still being evaluated for effectiveness. They are all flower or seed feeders, which reduce seed production and, thus, the infestations by this annual plant.

Introductions include three weevils, *Bangasternus orientalis* (Capiomont), *Eustenopus villosus* (Boheman), and *Larinus curtus* (Hochhut), and two flies, *Chaetorellia australis* (Hering), and *Urophora sirunaseva* (Hering).

Control methods such as burning, mowing, and cultivation are not compatible with the use of biocontrol insects because they can kill overwintering or active insects. Use of the herbicide clopyralid in the late winter was found to kill young seedlings and not directly injure the insects. In initial trials, the degree of control was greater than use of either method alone.

Chemical Control. Many types of herbicides are available to control yellow starthistle: selective, nonselective, pre-emergent, and post-emergent. Useful pre-emergent herbicides include atrazine, simazine, chlorsulfuron, and sulfometuron. These herbicides adhere to soil particles and can be blown offsite and injure nontarget plants under dry, windy conditions. Irrigation or rainfall after application will reduce this risk.

Post-emergent herbicides work best when applied at seedling or rosette stages. They are most effective when temperatures are warm, soil moisture is high, and plants are actively growing. These include glyphosate, 2,4-D, dicamba, triclopyr, picloram, and clopyralid.

- Glyphosate is nonselective and appropriate only for spot treatments. Addition of a silicone-based surfactant will give control even at early flowering stages.

- 2,4-D, dicamba, and triclopyr will not usually injure grasses. Offsite drift should be avoided. These herbicides do not have long residual activity, so

an additional application may be needed during the same season. The required rate of application will be low when plants are young and increase as the plants become larger.

- Picloram can be applied to seedlings, rosettes, or to plants beginning to bolt.

- Clopyralid should be applied before the bud stage.

4.2.6.7 Diffuse knapweed (Centaurea diffusa), Spotted knapweed (Centaurea maculosa)

Identification. Flower color is not a reliable method of distinguishing between knapweed species; neither is the dark spot on the bracts beneath the flower. The seedheads of diffuse knapweed have a long terminal spine, extending from the center rib of each bract, bordered by fine spines like teeth on a comb; the bracts of spotted knapweed have a very short tip. The taproot of spotted knapweed is usually much stouter.

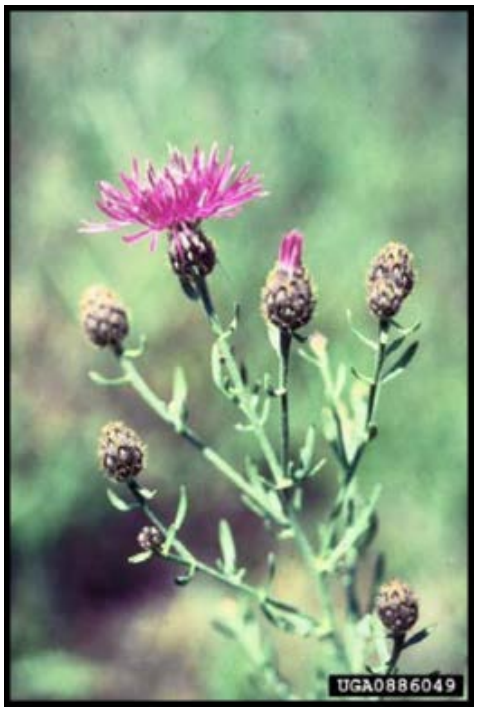

Figure 4.2.6.7.—*Centaurea maculosa*. (Photograph courtesy of Jim Story, U.S. Department of Agriculture.).

Ecology. These two knapweeds are biennial or short-lived perennial plants, reproducing entirely by seed. Seed production by both species is high, and the seeds are viable for at least 5 years in the soil. Diffuse knapweed frequently breaks at the stem after drying and spreads seed by tumbling. Spotted knapweed does not tumble but, like diffuse knapweed, seeds can be spread long distances when plants hitch rides on vehicle frames.

These knapweeds can invade both disturbed and undisturbed areas, but they are not common on cultivated or irrigated lands, or in areas of dense shade. Spotted knapweed tolerates dry conditions (as does diffuse knapweed) but also survives in areas of higher moisture.

Some reports indicate knapweeds may contain a carcinogenic compound. As a precaution, anyone working with knapweeds should wear gloves and avoid getting sap into open cuts. Workers should wash their hands and exposed skin with soap and water following contact with this plant.

4.2.6.7.1 Control methods

Mechanical or Physical Control. Hand pulling or digging is an effective control but is only practical for small infestations or sensitive areas. Pulling will need to continue for a number of years and should be done more than once per year.

Three times per year is suggested: once in the spring (rosettes), again just after plants have bolted, and a final time just before the flowers open. Pulling after a rain is best, because if a good portion of the taproot can be removed, the plant is unlikely to resprout. Cultivation to about 13 cm (5 inches) for diffuse knapweed and 18 cm (7 inches) for spotted knapweed has also been effective, but active revegetation is required after this method.

Mowing is not a control method, as the plants will regrow, flower, and produce abundant seeds on very short plants even if mowed as late as early flowering stage.

Mixed results are reported for the use of prescribed fire in knapweed control. In general, low-intensity fires do not destroy the root and plants resprout; diffuse knapweed has returned even after intense wildfires. Fire may make the plants more available to herbicide application, but mostly, they just increase the disturbance of the site and make it more susceptible to knapweed.

Cultural or Environmental Control. Repeated grazing can be used to manage knapweed infestations if attention is paid to timing and condition of other available forage. Knapweed is not preferred forage, so grazing should be directed by the condition of any desirable forage species present. Knapweed is most likely to be grazed if it is a young plant or if all other forage is dormant.

Biological Control. Overseas research in locating insect biocontrols is completed, but several plant diseases are still being researched. When choosing insects for a site, it is important to remember that they differ in effectiveness.

Simply reducing the seed production will not be successful in reducing plant density in established sites, because the plants compensate by increased seedling survival and higher reproduction. Diffuse knapweed seed production was determined to be a thousand times greater than the production necessary to maintain equilibrium of infestation, so even a 95-percent reduction in seed production may not reduce plant density. For this reason, insects that affect seed production often have little effect on an infestation, and root/crown feeders may be more effective.

Most insects that attack one knapweed also infest the other; the main difference appears to be their degree of preference. For example, *Cyphocleonus* is a weevil whose larvae infest knapweed roots, but it is not often found in diffuse knapweed, because these taproots are usually not large enough to support the larvae. On the other hand, the root-borer *Sphenoptera* prefers diffuse knapweed, probably because its larvae survive better under dry conditions, but spotted knapweed is able to grow under moister conditions.

Seed reducers include*: Bangasternus fausti*, *Larinus minutus,* and *L. obtusus* (three weevils); *Chaetorellia acrolophi, Terellia virens*, *Urophora affinis,* and *Urophora quadrifasciata* (four flies); and *Metaneria paucipunctella* (moth).

Root feeders include: *Agapeta zoegana*, *Pelochrista medullana,* and *Pterolonche inspersa* (three moths*); Cyphocleonus achates* (weevil); and *Sphenoptera jugoslavica* (beetle).

Chemical Control. Herbicides are most effective when applied in mid-May to early June, before or as the plants are bolting.

- Picloram is the most effective, and it provides nearly 100 percent control of spotted knapweed for 3 to 5 years. The period of control is shorter in areas with coarse soils or increased precipitation.

- Clopyralid is also effective at this stage, but it does not have as long-lasting residual effects as Picloram. It may need to be reapplied every 2 or 3 years.

- Dicamba and 2,4-D provide only short-term control of knapweeds and need to be reapplied annually until germination from the existing seed bank is depleted.

4.2.6.8 Russian knapweed (Acroptilon repens)

Identification. Russian knapweed (originally classified as *Centaurea repens*) has a bushy, branched growth form up to 3 feet tall. Foliage is grayish-green and hairy, with lower leaves lobed and smooth-edged upper leaves. Flowers are pink to purple and thistle-like in form, with papery tipped bracts.

Figure 4.2.6.8.—*Acroptilon repens*. (Photograph courtesy of Utah State University.)

Ecology. Perennial weed that spreads by both seeds and adventitious shoots from a creeping root system. It closely resembles diffuse and spotted knapweed, but it can be distinguished by the bracts beneath the flowers. In Russian knapweed, these bracts are rounded and have a paper-like edge.

Russian knapweed occurs in all soils types and can invade cultivated or undisturbed lands. Seed production averages about 1,000 seeds per plant, and seeds are viable for 3 to 5 years in the soil. Russian knapweed spreads mostly by its dark, scaly roots, which can extend as far as 6 m (20 ft) deep and grow horizontally to cover 12 square meters (130 ft^2) in 2 years. It establishes monocultures due to allelopathy and competition. Its bitter taste makes it highly unpalatable. Ingestion of fresh or dried plants is poisonous to horses.

4.2.6.8.1 Control methods

Mechanical or Physical Control. Mowing, pulling, cultivation, or prescribed fire are not able to control Russian knapweed, because the plant regenerates from the roots. Mowing at 2-week intervals over the entire growing season can be used to weaken the plant before an autumn application of herbicide.

Cultural or Environmental Control. Competition from perennial grasses can be useful to control Russian knapweed. Seeding of grasses should be done only after an application of herbicide to the knapweed. It can be useful to till the soil to reduce any allelopathic residuals in the soil from Russian knapweed. Grass seed of competitive species (such as smooth brome, streambank wheatgrass, or thickspike wheatgrass) is sown in the fall.

Biological Control. Insects and plant pathogens are being studied for use with Russian knapweed. Only the nematode *Subanguina picridis* (Kirjanova) has been approved for use. This nematode does not do well in dry areas. It must have moisture to move through the soil and infect additional plants. It is considered an effective biocontrol in favorable climates in Russia, but it has not had much impact in the United States.

Chemical Control. Herbicides alone cannot provide long-term control of Russian knapweed; competitive grasses need to be included after herbicide use for long-term management. A number of herbicides have been effective against Russian knapweed, but their results have varied. Control has been given by picloram, clopyralid, clopyralid + 2,4-D, glyphosate, metsulfuron, chlorsulfuron, and dicamba. Timing the application of herbicides can be critical and depends upon the particular herbicide and surrounding environmental conditions.

- Picloram provides the most consistent control, regardless of time of application, as long as the weed is actively growing. Good control is also seen the year following treatment; but depending on the rate used, another application may be needed the second year. Picloram will inhibit the germination of perennial grasses, so any seeding should be postponed until the year after treatment.

- Clopyralid applied during the bud-growth stage and in the fall gives control similar to picloram and has less impact on grasses. Clopyralid + 2,4-D applied at the same time gives slightly less control, especially the year following treatment. Application of chlorsulfuron and metsulfuron should be done at the bloom to postbloom stage, because earlier applications do not have as much effect. A surfactant should be added to both herbicides. Dicamba is also only effective when applied in the fall.

- Glyphosate can be applied during the bud-growth stage. Regrowth from the root systems will occur the same or following year, and additional applications will be necessary.

4.2.6.9 Dalmatian toadflax (Linaria dalmatica); yellow toadflax (linaria vulgaris)

Identification. Both species are members of the figwort family (*Scrophulariaceae*) and were introduced as ornamentals for their snapdragon like flowers. Leaves are alternate, but grow densely along stems and may appear opposite. Yellow toadflax is typically shorter than Dalmation toadflax (2 feet vs. 3 feet in height, respectively) and Dalmation toadflax displays increased branching near the top. Leaf shape can also be used to distinguish the two species; Dalmatian toadflax has pointed leaves that clasp the stem whereas yellow toadflax are longer and pointed at both ends.

Figure 4.2.6.9.—*Linaria dalmatica*. (Photograph courtesy of the Bureau of Land Management.).

Ecology. Both dalmatian toadflax and yellow toadflax reproduce by seed and underground roots, although seed production is less effective in yellow toadflax than Dalmatian toadflax.

Dalmatian toadflax plants can produce 500,000 seeds annually, which have a germination rate of about 75 percent, and can remain dormant in the soil for 10 years. Seed production and germination rates for yellow toadflax are much lower:

30,000 seeds per plant annually, with 10-percent germination. Vegetative reproduction can occur from the roots as early as 2 weeks after germination in yellow toadflax and 9 weeks after germination for Dalmatian toadflax.

These species have high genetic variability and can adapt to a wide variety of habitats. Yellow toadflax can be found from sea level to 1981 m (6500 ft), and Dalmatian toadflax grows at altitudes to 2804 m (9200 ft). They have a tolerance for low temperatures and coarse soils. Seedlings do not compete well with established vegetation, but mature plants are extremely competitive for available moisture.

4.2.6.9.1 Control methods

Mechanical or Physical Control. Pulling can be effective for small sites or sensitive areas, although it is labor intensive. Pulling must be repeated for up to 10 years and monitored for up to 15 years. It is important to get as much root as possible, since the plants spread by root. Pulling in wet or sandy soils is the most effective. Cultivation is also very intensive, requiring cultivation every week the first year and monthly the second year. Mowing is not effective for toadflax, and it may encourage more sprouts from the roots.

Burning is not a control for toadflax. The deep underground roots are too deep to be damaged by fire and, as with mowing, removal of the top growth can encourage vigorous sprouting from the roots.

Cultural or Environmental Control. Grazing does not control either species of toadflax. Dalmatian toadflax is waxy and unpalatable, and yellow toadflax contains a glucoside that is mildly poisonous to livestock. The perennial rootstalk allows any grazed plants to easily resprout.

Biological Control. Several insect species have been introduced as biological control agents for both toadflax species. Control of seed production will not eliminate infestations, as plants continue to spread locally via roots. Use of a number of these insects is still in the early stages, and it is too early to predict their effects on plant populations. Those agents which are the newest introductions include *Eteobalea intermediella* Treitschke and *E. serratella* Treitschke (root-boring moths), *Gymnetron linariae* Germar (root-galling weevil), and *Mecinus janthinus* Germar (stem-boring weevil). *Brachypterolus pulicarius* (L.) was an accidental introduction in about 1919; the adults feed on shoots, and the larvae impact seed production. Other agents include *Calophasia lunula* (Hufnagel) (defoliating moth), and *Gymnetron antirrhini* (Paykull) and *G. netum* Germar (seed-eating weevils).

Chemical Control. Permanent control cannot be achieved with herbicide treatment alone. Successfully controlled sites require retreatment for as long as 12 years. Dalmatian toadflax can be especially difficult, since the waxy leaf coating

protects the plant from herbicides. Studies into the effectiveness of particular herbicides have given variable results. For example, autumn applications of picloram have given good control of Dalmatian toadflax for 2 or 3 years at some sites and had no effect at others. Dicamba has given control at some sites, but triclopyr and fluroxypyr were ineffective against Dalmatian toadflax.

Yellow toadflax is not effectively controlled using 2,4-D, MCPA, 2,4-DB, MCPB, or mecoprop. A tank mix of picloram plus fluroxypyr applied prebloom gave 1 year of control, and picloram alone has shown variable results. Spot treatments of glyphosate, amitrole, diquat, and picloram can be used in conjunction with cultivation for good control.

4.2.6.10 Whitetop/hoary cress (Lepidium draba), tall Whitetop/perennial pepperweed (Lepidium latifolium)

Identification. These two species are both commonly referred to as "whitetop," causing much confusion. The alternate common name or, preferably, the Latin name should be used to avoid communication and management problems. *Cardaria* and *Lepidium* have similar clusters of small, white flowers atop 0.3- to 0.9-m (1- to 3-ft) tall plants and frequently form monocultures. *Cardaria* generally will have bloomed and set seed by mid-summer, but *Lepidium* flowers from early summer to fall. The leaves of *Cardaria* are covered with soft white hairs, while those of *Lepidium* are somewhat waxy or leathery.

Figure 4.2.6.10.—*Cardaria draba*. (Photographs courtesy of Colorado State Cooperative Extension.).

Ecology. Both *Cardaria* and *Lepidium* spread by seed and vegetatively by rhizome. Seed remains viable in the soil for no more than 3 years. Either species can be found in crop land, pastures, rangeland, and irrigation ditchbanks. Observations indicate that patches expand more quickly in wet years than in dry years. They are able to grow in saline environments and are a threat to riparian diversity.

4.2.6.10.1 Control methods

Mechanical or Physical Control. Mechanical control of these species is difficult because so much of the plant is underground and provides energy and buds for the plant to resprout. Because of this, hand pulling of aboveground plant parts is not effective. Digging or cultivation can provide control, but it must be done to 15 m (6 inches) deep and repeated every 1 to 2 weeks for at least two growing seasons to exhaust the root reserves. Be sure not to spread small root pieces, which can infest another site.

Repeated mowing does not provide control of Cardaria but can reduce seed production. Mowing of Lepidium at the bolting stage, followed by application of glyphosate at the flower bud stage, has been found to reduce weed density.

Cultural or Environmental Control. Flooding is a good control of Cardaria and Lepidium where it is possible. Prolonged flooding during the growing season (from May to September) is required, and revegetation should be done after dewatering to avoid reinfestation by weeds.

Competition from a dense planting of alfalfa has been used in crop fields to reduce the density of Cardaria.

Biological Control. No biological controls are available for either species. Biocontrol introductions are extremely unlikely due to related native and agricultural crop species.

Chemical Control. One effective chemical treatment for Cardaria is the use of Metsulfuron with a nonionic surfactant. This treatment should be applied before bloom and will need to be repeated upon regrowth. 2,4-D is moderately effective when applied before flowering. Two organochlorine pesticides, MCPA applied in bud stage and dimethyl tetrachloroterephthalate (DCPA) applied in full flower, gave good control. Picloram is not effective.

Lepidium can be controlled with a spring application of metsulfuron or chlorsulfuron with surfactant. Some research indicates that application of herbicides to *Lepidium* can also be effective at flowering or bud stage. Triclopyr and glyphosate have also given good control of *Lepidium*, but 2,4-D is not effective.

4.2.6.11 Kochia (Kochia scoparia)

Identification. Kochia ranges in height from 0.3 to 1.8 m (1 to 6 ft). The stems have many branches, giving the plant the shape of a Christmas tree. Leaves are long and narrow and often hairy on the undersurface. The flowers of kochia are inconspicuous; they lack petals and are found in the axils of the upper leaves.

Figure 4.2.6.11.—*Kochia scoparia*. (Washington State Noxious Weed Control Board).

Ecology. This annual plant reproduces only by seed, which is widely scattered in autumn when the dried stem breaks and the plant tumbles over the ground. The seeds germinate early the following spring, and few remain viable for more than a year.

Although kochia is readily grazed by livestock, toxicity and photosensitivity have been reported. This drought-tolerant plant has become a major problem in disturbed habitats such as places, roadsides, and uncultivated fields up to an altitude of 2591 m (8,500 ft).

4.2.6.11.1 Control methods

Mechanical or Physical Control. Mowing, hand pulling, and tillage can be effective against kochia, but they will be expensive and labor intensive. It is vital to remove the plant before seeds are produced and prevent any regrowth that may set seed. Since the flowers are inconspicuous, this means close inspection of the plants is necessary. Operations will need to continue for 2 to 5 years before control can be seen.

Biological Control. No biological control agents are available for this weed.

Chemical Control. Kochia has been shown to be resistant to acetolactate synthase (ALS) inhibitor herbicides (especially sulfonylurea herbicides such as chlorsulfuron and metsulfuron-methyl). Triazine-resistant (especially atrazine) varieties have also been reported, as well as varieties resistant to some synthetic auxins (especially dicamba). Herbicide resistance in kochia developed in fields where these herbicides were used repeatedly over several seasons. The best way of delaying resistance development in kochia is to rotate broadleaf herbicides. Herbicide rotation should be used as part of a long-term, integrated weed management strategy.

The key to using herbicides is to spray early. Kochia is one of the first weeds to emerge in the spring and is usually well advanced by the time other broadleaf weeds are ready to spray. Choose a herbicide that provides the widest possible window of application for kochia and the other weeds in your field. Good spray coverage is important for heavy infestation of kochia, especially when using contact herbicides.

4.2.6.12 Leafy spurge (Euphorbia esula)

Identification. Leafy spurge is a herbaceous perennial containing a milky latex sap that can irritate skin, eyes, and the digestive tract of humans and most grazing animals. Plants grow up to 0.9 m (3 ft) tall and have smooth leaves and stems. Heart-shaped, yellow-green bracts surround the inconspicuous green flowers clustered in an umbel form atop the plant.

Figure 4.2.6.12.—*Euphorbia esula*. (Photograph courtesy of U.S. National Park Service and John M. Randall, The Nature Conservancy.)

Ecology. This invasive weed is found primarily in pastures, rangelands, roadsides, and abandoned croplands and can thrive in a wide variety of habitats from moist riverbanks to dry ridges. Reproduction occurs by vigorous adventitious root stalks and seed. Buds are produced along the roots that can give rise to new stems and are a major factor in the spread and persistence Most of the roots are in the upper foot of soil, but some extend to a depth of 9 m (30 ft). The root system contains a large nutrient supply that can sustain the plant for years during control efforts. of this weed. These buds begin to be produced within 10 to 12 days after seedlings emerge and can be found on roots to depths of 3 m (10 ft) or more.

4.2.6.12.1 Control methods

An average of 140 seeds is produced per flowering stem, and these seeds are expelled up to 4.6 m (15 ft) from the plant by exploding seed pods. The seeds are also spread by floating down waterways, in mud, on equipment and animals, and in crops and hay. The seeds can remain viable for up to 8 years in the soil.

Mechanical or Physical Control. Hand pulling, mowing, and burning are ineffective against leafy spurge because it resprouts readily from its deep roots. They may be used to reduce seed production or improve herbicide coverage.

Cultivation has been used effectively where leafy spurge infests crop land, but it is not the best solution for rangeland or right-of-way areas.

Cultural or Environmental Control. Leafy spurge greatly reduces rangeland carrying capacity because cattle avoid it. Sheep and goats do not suffer ill effects from the plants and can be carefully managed to assist control of the weed. Information is available on stocking rates, timing, grazing rotations, and use in conjunction with other control methods. It is important that animals grazing plants with seeds be kept out of uninfested areas until the seeds clear their digestive tracts.

Biological Control. Biological controls or grazing should not be used to control small infestations of leafy spurge; these are best eliminated quickly with herbicides. For successful control using insects, it is important to match the habitat requirements of the biocontrol agent with the conditions at the site. For example, some flea beetles do best in dry and sunny sites, while others need moister soils. All flea beetles need sandy or loamy soils, because clay soils restrict access to the fine roots needed by larvae. Other agents have their own requirements; a stem borer prefers shady and moister areas, and a gall midge is adversely affected by wind.

It is likely that a number of different species or different biotypes of leafy spurge have been introduced into the United States, because some biocontrol agents are more effective on some leafy spurge biotypes than others. A great deal of research has been done on the collection and use of the various flea beetles. The flea beetle adults feed on the foliage, and significant damage is done by larval feeding in the roots. Some of the flea beetles having significant impacts on leafy spurge are *Apthona nigriscutis* Foudras, *A. czwalinae* Weise, *A. lacertosa* Rosh, *A cyparissiae* (Koch), and *A. flava* Guillebeau. Other available agents include *Oberea erythrocephala* Schrank (a stem- and root-boring beetle), and *Spurgia esulae* Gagne (a shoot-tip gall midge).

Chemical Control. The distinction between the appearance of bracts and true flowering is important for timing herbicide application to leafy spurge. Herbicide applications of picloram, dicamba, and 2,4-D are more effective on plants with developing true flowers than on plants with developed bracts but undeveloped flowers.

- Picloram is one of the most effective herbicides available for leafy spurge control; applied during the true-flower stage, it will give 90-percent control the year after treatment, declining to 70-percent the third year. It is expensive when used over large acreage, so it is often mixed with the less-costly 2,4-D. This can provide 85-percent control when applied annually for 4 years at true-flower stage. In hard to reach areas, it may be more cost effective to stay with the higher rate for longer control.

- Dicamba has met with some success in the control of spurge but is costly and breaks down quickly in the soil, requiring annual application. Picloram is clearly more effective than dicamba in the eastern portion of spurge country (North and South Dakota, Nebraska, Minnesota, and Wisconsin) due to its longer soil residual activity. However, in Western States, such as Wyoming, Montana, and Colorado, where rainfall is relatively low, dicamba is not leached or broken down as quickly and has been found to give quite effective control.

Control of leafy spurge among trees can be done with amine formulations of 2,4-D in the spring, or glyphosate in the late summer or fall when grasses are dormant. Drift from either herbicide onto tree foliage or bark should be avoided. Control of leafy spurge near water is limited by the label of many herbicides.

Some options are to use glyphosate with approved nonionic surfactant applied mid-July to mid-September; or 2,4-D aquatic formulations applied at true flower.

4.2.6.13 Field bindweed (Convulvus arvensis)

Identification. This perennial vine has funnel-shaped flowers that resemble those of morning glories, and it spreads by rhizome and seed. Taproots can extend 3 m (10 ft) deep into the soil and store nutrients that can sustain the plant during control efforts.

Field bindweed is sometimes confused with wild buckwheat, *Polygonum convulvus* L., which is an annual weed that reproduces only by seed. In flower, it can be easily distinguished because flowers of wild buckwheat are clusters of inconspicuous greenish-white flowers, compared to the showy, funnel- shaped flowers of bindweed. Out of flower, wild buckwheat can be discerned because a papery sheath surrounds each leaf node; bindweed does not have such sheaths.

Another variable difference is that leaves of wild buckwheat are heart shaped, but bindweed leaves are usually shaped like an arrowhead or spade.

Ecology. Field bindweed is a serious weed in most of the United States. It is adapted to many habitats and causes problems in agricultural fields, orchards, vineyards, roadsides, ditchbanks, and riparian areas. Seed production is moderate, but seeds are viable in the soil for up to 50 years.

Figure 4.2.6.13.—*Convulvus arvensis*. (Photograph courtesy of The Nature Conservancy.)

4.2.6.13.1 Control methods

Mechanical or Physical Control. Mowing is not recommended because the low-growing plants are easily missed. Hand pulling is effective, but must be repeated regularly, depending on the growing conditions, every 4 to 14 days. Repeated cultivation is needed for field bindweed control, because plants can regenerate from roots about 1.4 m (4.5 ft) deep. Cultivation to 15 cm (6 inches) deep should be repeated about every 2 weeks throughout the growing season. Almost all current recommendations for cultivation suggest combining it with herbicides.

Cultural or Environmental Control. In general, species that grow vigorously during the winter and early spring can compete for light and water when bindweed begins to grow. In areas where light is already limited, such as under trees, competition may give excellent control. Some areas have had success with plantings of early season, competitive perennial grasses. Agricultural areas have successfully used winter wheat and alfalfa.

Biological Control. Use of biocontrol agents against field bindweed is still in the early stages. *Aceria malherbae* Nuzacci, a gall mite, can stunt the growth of plants. Populations of the mite have recently been established and proved effective in Texas and Montana. *Tyta luctuosa*, a moth, is not currently widely available for testing. A mycoherbicide (*Stagonospora convolvuli* Denis and Schiff.) was effective in recent trials in Switzerland, but it would need to be applied annually. Additional pathogens and insects are being investigated.

Chemical Control. Long-term control of field bindweed from herbicides depends on movements of a sufficient amount of herbicide through the root system to kill the roots and root buds. Timing of herbicide application is important and must take into account the developmental stage of the plant and available soil moisture.

Fully grown plants (budding or flowering) will be more likely to translocate herbicides to the roots. Drought may cause the plants to become somewhat dormant and less able to absorb or move the herbicides to the roots. Because of long seed viability and tremendous food reserves stored in the roots, repeated chemical and/or mechanical control measures must be used.
Some areas of bindweed seem to be resistant to the herbicides, 2,4-D, or glyphosate. Results from all herbicide applications should be monitored, so if resistant bindweed is present, it can be detected and controlled with another herbicide or method.

- 2,4-D is widely used for field bindweed because it will kill most broad-leaved plants (dicots) but will not damage most grasses and other monocots. 2,4-D applied to one shoot is not readily translocated to other shoots, so it may not work well in very dense patches where some branches are shielded from herbicide application.

- Dicamba was shown to be more effective than 2,4-D and picloram against field bindweed, but it is generally more expensive.

- Glyphosate does not provide consistent control of field bindweed. Field bindweed suffering drought stress and plants grown from seed (instead of vegetative propagules) are more resistant to glyphosate. Control efficiency may decrease as the relative humidity increases.

4.2.6.14 Japanese knotweed (Ppolygonum cuspidatum)

Identification. Japanese knotweed is similar in appearance to giant knotweed and a hybrid Bohemian knotweed. All are perennial, bamboo-like plants that grow 5-16 ft tall. Stems are hollow and spread is primarly through rhizomes. Stems are hollow. Japanese knotweed leaves are large and spade-shaped, with bumps on the underside. Flowers are greenish-white and form clusters in late summer.

Figure 4.2.6.14.—*Polygonum cuspidatum*. (Tom Heutte, USDA Forest Service, www.invasives.org).

Ecology. Knotweeds can regrow from root fragments. They can tolerate many environmental conditions, growing near water, in disturbed areas, and along roadways. They can clog waterways and increase bank erosion.

4.2.6.14.1 Control methods

Mechanical or Physical Control. Can spread by root fragments, so if cut or pulled, plant must be disposed of properly.

Cultural or Environmental Control. Cover with heavy black plastic and reseed. Burning is ineffective.

Biological Control. No biocontrol agents are available.

Chemical Control. Glyphosate can be used to control Japanese knotweed.

4.2.6.15 Purple loosestrife (Llythrum salicaria)

Identification. Purple loosestrife is a perennial forb. It grows 2-8 ft tall, with 4-sided stems and lance-shaped leaves (CDA 2015). Flowers grow on a long vertical stalk and are a bright pink/purple color. Flowers appear from late June through September.

Figure 4.2.6.15.—*Lythrum salicaria*. (commons.wikimedia.org).

Ecology. Purple loosestrife is often found along waterways or in wetland areas. It can impede waterflow and will outcompete native vegetation. A single plant can produce 3 million seeds per year and they can remain viable in the soil for 5 to 20 years. The plant can also regrow from root fragments. Purple loosestrife populations are difficult to control.

4.2.6.15.1 Control methods

Mechanical or Physical Control. Hand removal for small populations. During flowering, flowerheads must be cut and disposed of before chemical control is attempted.

Cultural or Environmental Control. Prevent establishment and minimize disturbances.

Biological Control. *Galerucella pusilla* and *Galerucella calmariensis* are leaf eating beetles. *Hylobius transversovittatus* is a root-boring weevil and *Nanophyes marmoratus* is a flower-feeding weevil.

Chemical Control. Triclopyr, glyphosate, and 2,4-D are effective chemical controls.

4.2.6.16 Poison hemlock (Cconium maculatum)

Identification. Poison hemlock is a biennial that grows 4-8 ft tall, with smooth, hollow stems that have distinct purple spots. Leaves have a fern-like appearance. During the first year, it will form a rosette, and in the second it will bolt a large stem with white, umbrella like flowers before dying. Flowering will usually occur from June to July, with mature fruit in August to September.

Figure 4.2.6.16.—*Conium maculatum*. (King County, WA Noxious Weed Control Program).

Ecology. Habitats include disturbed sites, riparian areas, and ditches. All parts of the plant are poisonous.

4.2.6.16.1 Control methods

Mechanical or Physical Control. Hand removal of the entire plant, including the taproot can be effective. Be careful to avoid spreading seeds. Mowing to reduce seed production can limit the spread.
Cultural or Environmental Control. Poison hemlock can be outcompeted by planting native species through broadcast or drill seeding.

Biological Control. The hemlock moth (*Agonoptetix alstroemericana*) larvae feeds on leaves, young stem tissue, flowers, and seeds, leading to the death of the plant.

Chemical Control. The following herbicides can be used to control poison hemlock: 2,4-D, Grazon P+D, Escort, and Telar.

4.2.7 Terrestrial trees and shrubs

4.2.7.1 Saltcedar (Tamarix spp.); Russian Olive (Elaeagnus Angustifolia)

Identification. Saltcedar trees can grow to about 6 m (20 ft) tall. They have small, scaly, cedar- like leaves that exude salt brought up from the soil by the roots. The bark on new growth is smooth and reddish brown. Thousands of pink or white flowers are produced over an extended period of time in spring and summer.

Russian olive normally reaches heights of 3 to 8 m (10 to 25 ft). Trunks and branches have long, woody thorns and long, narrow, silvery-green leaves. Clusters of small, fragrant yellow flowers give way to small, one-seeded fruits resembling olives.

Figure 4.2.7.1.—*Tamarix* spp. (Photo credit: Tim Higgs, August 2008, Grand County (Utah) Weed Department.).

Ecology. These two shrubby, fast-growing deciduous trees were once planted deliberately (ornamental, erosion control, windbreaks, wildlife habitat), but they have now become serious weed problems, especially in riparian areas. Cottonwoods (*Populus* spp.) and willows (*Salix* spp.) need full sunlight to reestablish themselves from seed and cannot grow in the shade of these invasive trees. The result is a permanent conversion of native riparian areas to areas dominated by these non-native trees, which often provide inferior habitat for native insects, birds, and animals. Established trees of both species are salt, drought, fire, and flood tolerant.

One mature tree can produce 500,000 seeds per year, which are dispersed by wind or water. These tiny seeds are short-lived and must germinate within a month or two after dispersal. Saltcedar will resprout vigorously from cut stumps and roots and will produce roots on buried or submerged stems or stem fragments. Saltcedar can increase fire potential, clog water channels, widen flood plains, and increase soil erosion due to floods. Its deep taproot and numerous surface roots decrease the moisture available to other vegetation and may lower water tables due to a higher rate of water use. Salt exuded from the leaves increases the salinity of soils beyond the range tolerated by most native plants.
Russian olive fruits are ingested by birds and seeds are readily dispersed, remaining viable for up to 3 years. Russian olive can also reproduce vegetatively via root suckers and adventitious buds on root crowns.

4.2.7.1.1 Control methods

Mechanical or Physical Control. Mowing, chaining, root plowing, or cutting alone will not usually control saltcedar or Russian olive because of their ability to resprout vigorously from their roots. Dry conditions can increase the effectiveness of mechanical controls. These methods can be effective when used in conjunction with herbicide treatments. Large-scale use of chaining or root- plowing is not appropriate where a good percentage of native or desirable vegetation is interspersed.

Fire is not a reasonable control method for saltcedar where it occurs as a component of native communities; cottonwood does not resprout vigorously following fire, while saltcedar does. However, in monotypic stands of saltcedar, burning followed by herbicide application to the resprouts can give excellent control. Burning during the hottest part of the summer, when plants experience the greatest water stress, is likely to yield the best results. Felling 20 to 25 percent of the largest saltcedar plants several months prior to burning helps create enough dry ground fuel to carry a fire.

Cultural or Environmental Control. Long-term inundation of saltcedar is an effective control where water levels can be controlled. No definite guidelines have been established. On site, flooding was used for 28 months; on another site, mature trees were killed after only 90 days of root-crown submergence or 43 days of total top growth submergence. In another study, trees were cut back and the resprouting shoots were flooded. Saltcedar will generally re-invade the site after the water is lowered if further management and revegetation is not done. The effects of prolonged inundation on Russian olive are not known.
Attempts to kill saltcedar by lowering local water tables by draining and dredging may be counterproductive. Saltcedar is able to extract water from deeper in the soil profile than the native species of cottonwood and willow. Therefore, draining and dredging that lead to local declines in water table depth could promote saltcedar at the expense of desirable native plants.

Biological Control. Biocontrol insects for use against saltcedar are currently in the research phase and not widely available. Two of the most promising for widespread use are leaf feeders: the beetle *Diorhabda elongata* (Brullé) and the weevil *Coniatus tamarisci* Fabricius. The mealybug *Trabutina mannupara* (Hemprich et Ehrenberg) will only be useful in areas without freezing temperatures. A leaf-hopper (*Opsius stactogalus* Fieber) that is host-specific to saltcedar was not intentionally released but is now widespread. In some areas, this leafhopper periodically defoliates plants, but it is not considered to be an effective control agent.

No biological control agents are available for Russian olive. Some natural diseases already present in North America affect Russian olive. Two caused by fungus are *Verticillium* wilt and *Phomopsis* canker. Phomopsis canker (*Phomopsis arnoldiae*) outbreaks have become quite severe in Wisconsin and

Kansas and limit the use of the tree as a cultivated species. The exact cause or agent of Russian olive decline and gummosis is unknown, although environmental stress and root fungus are likely involved.

Chemical Control. Herbicidal control of saltcedar and Russian olive can be done by applying herbicides to foliage of an intact plant or resprouted shoots, to the cut stump, or to the basal bark of an intact plant.

- Foliar application. Imazapyr, or imazapyr in combination with glyphosate can be used as a foliar spray on intact plants. Depending on the size and density of the stand and the presence of desired vegetation, they can be applied either aerially or using truck-mounted equipment. After foliar applications, treated plants should not be burned or bulldozed for two growing seasons, because it will cause resprouting. When burning or mechanical methods are used to first remove trees, resprouts can be treated when they are 0.9 to 1.8 m (3 to 6 ft) tall with imazapyr, imazapyr plus glyphosate, or triclopyr.

- Recommendations for Russian olive control include: 2,4-D + triclopyr, 2,4-D + dicamba, dicamba, glyphosate, and imazapyr.

- Cut-stump application. Cut-stump method is appropriate for modest-sized areas (2 hectares or smaller; 5 acres) of saltcedar and Russian olive. The effectiveness of this treatment highly depends on the skill of the field workers—poor technique leads to poor results. The cut-stump treatment may be more effective if done while the plants are translocating nutrients from the leaves and stems into their roots (in the fall). The best choice of herbicide for this application appears to be the triclopyr herbicides (Garlon 4 and Pathfinder) diluted and undiluted products were used. The basic steps for this technique are:

- Cut stems of saltcedar within 5 cm (2 inches) of the ground surface.

- Apply herbicide within a few minutes of cutting to the entire surface of the stem, especially at the cambium.

- Treat any resprouted foliage between 4 to 12 months after the initial treatment.

- Basal bark application. This method eliminates the need to cut down the trees, resulting in major savings in labor, and produces no debris to haul away or burn. Disadvantages are the higher amount of herbicide required (up to five times that needed for stump-cut control) and lower mortality than the stump-cut method. Triclopyr is effective on saltcedar plants with a basal diameter of less than 10 cm (4 inches). Triclopyr is also effective

on small Russian olive trees with smooth bark. With larger trees having thick and furrowed bark, the sprayed area must extend upward to include some smooth bark, but it may still only give about 50-percent control.

4.2.7.2 Tree-of-Heaven (Ailanthus altissima)

Identification. Tree-of heaven can reach 1.8 m (6 ft) in diameter and 24-30 m (80-100 ft) in height. Leaves are pinnately compound, with a central stem 0.3-1.2 m (1-4 ft) in length and 10-40 lance shaped leaflets. Unlike some native species, the leaves are smooth edged. Seeds are 2.5-5 cm (1-2 inches) long and are wing shaped. They are typically found in dense colonies and can disperse by seeds or root suckers.

Ecology. *Ailanthus altissima* will grow in disturbed, riparian, and urban areas, as well as along roadways and ditches. It produces chemicals that can prevent the establishment of other plants.

Figure 4.2.7.2.—*Ailanthus altissima*. (Washington State Noxious Weed Control Board).

4.2.7.2.1 Control methods

Mechanical or Physical Control. Cutting and mowing are not effective. The tree can resprout from a cut trunk or root suckers which are very difficult to remove. If seedlings are hand-pulled, remove the entire root system.

Cultural or Environmental Control. Prevention.

Biological Control. The *Eucryptorrhyncus brandti* weevil is being tested for controlling the tree-of-heaven. In addition, a native vascular wilt fungus, *Verticillum nonalfalfae*, has been observed to kill tree-of-heaven, and can be transmitted by the weevil. It is currently undergoing range testing.

Chemical Control. The following herbicides can be used to control tree-of-heaven: glyphosate and triclopyr. Timing of application is critical to ensure that roots are controlled and the plant does not regrow.

5 ANIMAL PEST MANAGEMENT

5.1 Introduction

Animal pests can cause a variety of problems, including increased maintenance requirements, damage to hydraulic structures, and safety or nuisance issues. Integrated Pest Management practitioners should bear in mind that failure to control potentially threatening animal activity could ultimately result in major damage to or failure of canals and earthen dams. Other pests may impact personnel or people recreating in an area by being a nuisance or causing hazards to health. The potential threat animals pose to the integrity of structures may justify control measures; however, cost-benefit ratios often cannot be easily measured or defined in economic terms.

5.2 Aquatic invertebrates

5.2.1 Mollusks

5.2.1.1 Zebra and quagga mussels (Dreissena spp.)

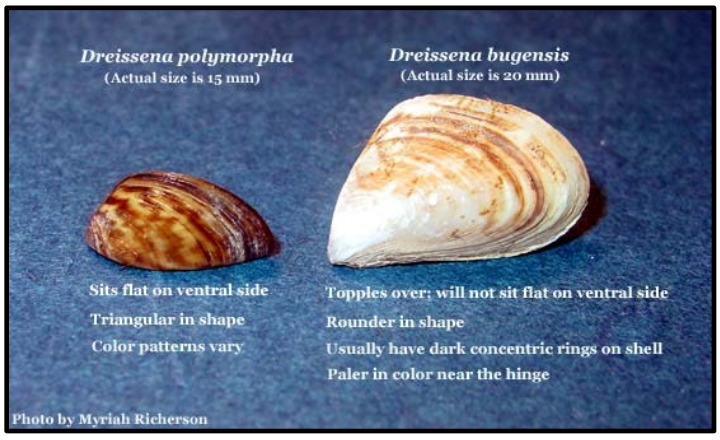

Figure 5.2.1.1.—Morphological differences between zebra and quagga mussels include average size, shape, and symmetry between valves. (Myriah Richerson, USGS)

Two species of dreissenid mussels, *Dreissena polymorpha* (zebra mussel) and *Dreissena rostriformis bugensis* (quagga mussel), have become established in freshwater lakes, reservoirs, and rivers in the United States. These invasive

mussels pose significant challenges for Reclamation and all agencies and industries that manage water. Invasive mussels are prolific breeders and settle on or within water facility infrastructure such as water intakes, gates, diversion screens, hydropower equipment, pumps, pipelines, and boats. Infested water and hydropower infrastructure can fail or choke off water transmissions. Invasive mussels negatively impact the natural ecology, which can be detrimental to native and endangered species, including native fisheries.

Maintaining and operating water supply and delivery facilities, water recreation, and other water dependent industries and economies in mussel infested water bodies are dramatically more expensive and complex. Public recreation may also be severely impacted by mussel infestations, from shell fragments degrading swim beaches to increased requirements and cost for boaters to have their watercraft inspected and decontaminated, and potential impacts on populations of game fish.

Identification. The mussels attach in clusters to submerged objects. Adults average 2-3 cm in length but may reach 5 cm (2 inches). The shell is marked by alternating wavy dark (green/black/brown) and light (yellow/cream/white) bands.

Ecology. Quagga and zebra mussels arrived in the United States from Europe in the 1980s and spread to many eastern waterways, rivers, and lakes. Quagga mussels were discovered in Lake Mead, Lake Mojave, and Lake Havasu on the Colorado River in January 2007. Zebra mussels were confirmed to be present in San Justo Reservoir in California in January 2008.

The mussels spread in numerous ways, mainly by floating in the currents of the water body or by "hitching" a ride on a boat or other water vessels that are used in infested water and then transported to another water body. Knowledge and experience in the Eastern United States indicates that once introduced, the mussels are almost impossible to eradicate in water bodies and facilities comparable to Reclamation facilities. A key observation of quagga and zebra mussels in the Western States is not all contemporary measures can be applied to other facilities; one size does not fit all. The observations show that mussels react differently at different facilities because of water temperature, chemistry content differences, and a host of other unknown factors.

Dreissenid mussels are prolific breeders. A mature female mussel produces several hundred thousand eggs per season. Egg release usually begins when the water temperature warms to about 12 degrees Celsius (°C) [54 degrees Fahrenheit (°F)] and continues until the water cools below the same temperature in the fall.

Eggs are fertilized outside the mussel's body and develop into free-swimming larvae called veligers. It is estimated that only 1 to 3 percent of the veligers survive to adulthood. Mussels usually reach sexual maturity within a year. They grow rapidly, nearly 2.5 cm (1 in) in length in their first year, adding another 1.3 to 2.5 cm (0.5 to 1 in) their second year. European studies report mussels may live

4 to 6 years. The maximum lifespan in Lake Erie seems to be 3 years, but the data are not sufficient to know what to expect in other North American bodies of water.

Dreissenid mussels generate fibers known as byssal threads from a gland in the foot. These threads attach to hard surfaces with an adhesive secretion that anchors the mussels in place. Mussels can also colonize soft bottoms when hard objects are associated with the mud. Native mussel shells can also serve as a substrate (base) for settling veligers. As the mussels grow, they will also serve as substrate for additional colonization, forming what is known as a druse.

Mussel colonies show little regard for light intensity, depth, or temperature, when it is within a normal environmental range. The life stage most sensitive to low temperature is the veliger stage, and juveniles are more sensitive than adults. All life stages are sensitive to low levels of dissolved oxygen, particularly as temperature increases. Colonies grow rapidly wherever oxygen and particulate food are available and water currents are not too swift, generally less than 1.8 m/sec (6 ft/sec). Colonies are rare in wave-washed zones, except for sheltered nooks and crevices. In most lakes, the greatest densities of adult mussels occur at depths ranging from 1.8 to 13.7 m (6 to 45 ft).

Mackie and Claudi (2010) assembled tables of parameters to define the risk of infestation to waterbodies in North America. Zebra (Table 2.1) and quagga (Table 2.2) mussels have slight differences in ecological tolerances. Moderately hard-water lakes with calcium (Ca2+) concentrations above 12 mg/L, alkalinity above 50 mg CaCO3/L, and pH above 7.2 are suitable for adult mussels. Mussels are sensitive to acidic waters. Below pH 6.8, adult mussels have a net loss of calcium, sodium, and potassium to the surrounding water; however, they can adapt. After several days at pH 5.5-6.0, adults adapt to acidic conditions, and their net rate of ion loss decreases. Veligers are more sensitive to low pH than adults. Temperature can limit the extent of mussel colonization. Lakes with prolonged periods above 12 °C (54 °F) and with maximum temperatures of 18 to 23 °C (64 to 74 °F) provide optimum conditions for growth and reproduction. Each mature female produces several hundred thousand eggs during the breeding season, which occurs when the water temperature is above 12 °C. Adults are unable to survive prolonged exposure to temperatures above 32 °C (90 °F). They can tolerate temperatures as low as 0 °C (32 °F), provided they do not freeze.

Table 5.2.1.1-1.—Parameters for risk of zebra mussel infestation (From Mackie and Claudi 2010)

		Potential for Infestation		
Parameter	**None**	**Low**	**Moderate**	**High**
Mean Temperature (oC)	<10 or >32	26-32	10-20	20-26
Calcium (mg/L)	<8	8-15	15-30	30-80
pH	<7.0 or >9.5	7.0-7.8 or 9.0-9.5	7.8-8.2 or 8.8-9.0	8.2-8.8
Alkalinity (mg CaCO3/L)	<30	30-55	55-100	100-280
Hardness (mg CaCO3/L)	<30	30-55	55-100	100-280
Dissolved Oxygen (mg/L) (% saturation)	<3 (<25%)	3-7 (25-50%)	7-8 (50-75%)	>8 (>75%)
Chlorphyll a (mg/L)	<2.5 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total phosporous (mg/L)	<5 or >50	5-10 or 35-50	10-25	25-35
Total nitrogen (mg/L)	<75 or >750	75-150 or 525-750	150-375	375-525
Secchi depth (m)	<1 or >8	1-2 or 6-8	4-6	2-4

Table 5.2.1.1-2.—Parameters for risk of quagga mussel infestation (From Mackie and Claudi 2010)

		Potential for Infestation		
Parameter	**None**	**Low**	**Moderate**	**High**
Mean Temperature (oC)	<2 or >30	2-10 or >28	10-16 or 24-28	16-24
Calcium (mg/L)	<10	10-12	12-30	30-120
pH	<7.0 or >9.5	7.0-7.8 or 9.0-9.5	7.8-8.2 or 8.8-9.0	8.2-8.8
Alkalinity (mg CaCO3/L)	<35	35-42	42-100	100-420
Hardness (mg CaCO3/L)	<35	35-42	42-100	100-420
Dissolved Oxygen (mg/L) (% saturation)	<4 (<25%)	4-7 (25-50%)	7-8 (50-75%)	>8 (>75%)
Chlorphyll a (mg/L)	<2.0 or >25	2.0-2.5 or 20-25	8-20	2.5-8
Total phosporous (mg/L)	<5 or >50	5-10 or 35-50	10-25	25-35
Total nitrogen (mg/L)	<75 or >750	75-150 or 525-750	150-375	375-525
Secchi depth (m)	<1 or >8	1-2 or 6-8	4-6	2-4

Ecological Impacts. Zebra and quagga mussels can impact ecosystems by filtering phytoplankton from large amounts of water. The increased water clarity that results can encourage growth of submersed aquatic macrophytes and alter fish communities. Mussel fecal material and undigested material expelled from the siphon can change benthic invertebrate communities by altering food sources and bottom substrates. Changes in the abundance of many aquatic taxa have been correlated with zebra/quagga mussel abundance. Native species also compete with invasive mussels for space and food. Populations of burrowing unionid clams have been nearly eliminated from some lakes because of dreissenid mussel attachment to their shells.

Other Impacts. Hydroelectric powerplants, municipal drinking water facilities, and other water-using industries are likely to be most heavily impacted by zebra and quagga mussel populations. Mussels colonize the inner surfaces of pipes, diminishing the flow rate through water intake pipes. Unless preventive measures are taken, larval stage mussels colonize the interior parts of turbines and other equipment, leading to costly repairs. Preventive measures, such as retrofitting

backwash filters or pre-chlorination devices for water intake pipes, are also costly. Great Lakes industries have spent millions of dollars combating and preventing invasive mussel damage.

Zebra and quagga mussels can also attach to water intake pipes of boats, preventing sufficient flow of coolant water, leading to engine failure. Mussel attachment to boat hulls increases drag and decreases fuel efficiency. Removal of mussels from boat hulls is often time consuming and costly. Antifouling paints are expensive; some are highly toxic, heavily regulated, and need to be applied by a licensed specialist.

The full economic impact of dreissenid mussels is still evolving. Studies report that zebra and quagga mussels hasten the corrosion rate of iron and steel structures at the point of attachment. Enhanced growth of aquatic weeds resulting from increased water clarity has led to taste and odor problems in drinking water supplies, necessitating expensive and aggressive water treatment procedures.

Ecological impacts include declines in native bivalve populations, extended macrophyte ranges due to increases in water clarity, and changes to the natural trophic structure. Effects are complex, and steady-state systems are only now becoming established in the Great Lakes region.

5.2.1.1.1 Control methods

Boat traffic is the major vector spreading zebra and quagga mussels to new locations. They can attach to the hull, motor, or trailer, or survive in live wells, bait buckets, ballast tanks, or other standing water.

Controlling the movement of contaminated boats and other equipment is the only significant means of slowing the spread of mussels from infested waters. The most effective and least environmentally damaging method of control is to drain the boat and let it dry completely before transferring it to other waters. Although the veligers are sensitive to drying, individual adult mussels are very hardy and can survive for up to 30 days out of water, especially in moist environments. Decontaminating the boat with hot water (at least 60 °C [140 °F]) using a high-pressure washer is also effective in removing mussels attached to boat surfaces. Water hotter than 43 °C (110 °F) will kill veligers, and 60 °C (140 °F) will kill adults. Do not use saltwater and chlorine water mixtures, as both mixtures are very toxic to other organisms and may also damage your equipment.

Clean, Drain, and Dry your boat. Most Western states have instituted watercraft inspection and decontamination (WID) procedures to limit the spread of invasive species. For the most current information on inspection and decontamination methods, use the Uniform and Minimum Protocols and Standards (UMPS) found at: www.westernais.org/.

5.2.1.2 New Zealand mud snail (Potamopyrgus antipodarum)

Identification. New Zealand mud snails (NZMS) are an invasive freshwater snail. They are small (up to 6 mm), with a dextral (right-handed coiling), elongated shell with 5-8 whorls separated by deep grooves. The shell aperture is oval, and has an operculum that can be closed, allowing them to survive out of water or while passing through a fish digestive system. Shell color tends to be dark to very dark brown.

Figure 5.2.1.2.—New Zealand mud snails (*Potamopyrgus antipodarum*) are often spread by anglers and boaters. (Dan Gustafson, Montana Natural Heritage Program)

Ecology. New Zealand mud snails feed on plant and animal detritus. They prefer streams and rivers and can typically be found on the underside of rocks. Despite the name, they are rarely found in muddy areas. All NZMS populations in the US are female, reproduce by cloning, and can produce up to 120 offspring every 3 months. One individual can quickly start a new population. NZMS densities have gone from undetectable to 10,000 – 300,000 individuals per square meter in Yellowstone National Park, where they may outcompete native grazers and other macroinvertebrates. Large populations also have the potential to impact the delivery of water through canals or other infrastructure.

5.2.1.2.1 Control methods

Control is nearly impossible once NZMS become established in a waterbody, although researchers continue to investigate the potential of biological control through a host specific parasite. Because eradication is impossible, preventing establishment is critical. New Zealand mud snails are often spread by trout fly-fishers and other anglers. The snails can close their operculum and survive in mud attached to boots or other gear for up to a month. Educating anglers about how to clean their gear is critical to halt the spread of NZMS. Gear that may have come

in contact with NZMS can be decontaminated by: (1) freezing overnight, (2) soaking in hot water (120° F) for 5 minutes, or (3) soaking in undiluted Formula 409 for 10 minutes.

5.2.2 Aquatic arthropods (crayfish, crabs)

5.2.2.1 Crayfish (Orconectes spp., Procambarus spp., etc.)

Figure 5.2.2.1.—The rusty crayfish (*Orconectes rusticus*) is invasive in several Western states. (Missouri Department of Conservation).

Identification. There are 390 known species of crayfish in North America (Helfrich et al. 2009). They can be identified by differences in the shape of the claws, shape of the pleopods, and appearance of the thorax. Color is not a reliable identifier.

Ecology. Crayfish are a significant food source for many animals and are also consumed by people. Some species of crayfish can cause damage to Reclamation facilities by burrowing into the banks of reservoirs and canals. Changing water levels can stimulate new burrow creation, increasing potential damage (Helfrich et al. 2009). A crayfish burrow can be identified by a cone-shaped mound of mud pellets and serves as a refuge from predators or a nursery during breeding (Helfrich et al. 2009). Crayfish will also overwinter in their burrows and emerge when the water nears 40 °F (4 °C) (Helfrich et al. 2009).

Crayfish have been introduced through the dumping of excess fish bait and both legal and illegal stocking. Crayfish can also migrate long distances over land.

5.2.2.1.1 Control methods

Biological Control. Sportfish, including trout, bass, catfish, and large bluegills, eat crayfish (Helfrich et al. 2009). Other animals, such as turtles, herons, ducks, and racoons, are also predators of crayfish and can help reduce their population (Helfrich et al. 2009).

Mechanical Control. A variety of crayfish traps are available. Traps are generally simple and consist of a funnel entrance and a bait of fresh meat or canned dog food. Traps are most effective when left overnight. Trapping alone may be able to suppress a crayfish population but is unlikely to eradicate it (Bills and Marking 1988). In areas where the movement of crayfish is not prohibited, trapped crayfish can be cooked and eaten.

Chemical Control. No chemicals are currently registered for crayfish control.

5.2.2.2 Chinese mitten crab (Eriocheir sinensis)

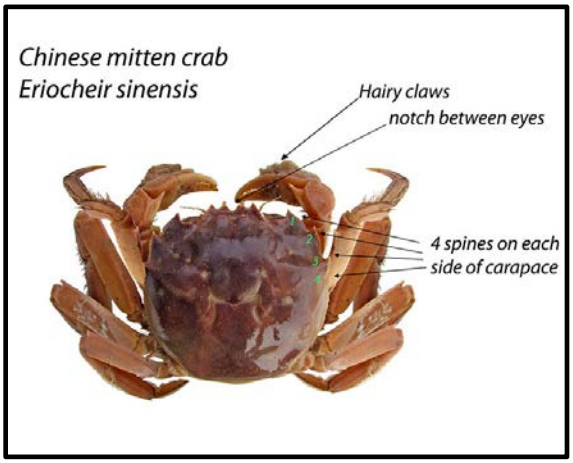

Figure 5.2.2.2.—The Chinese mitten crab (*Eriocheir sinensis*) can be identified by hairy claws, a notch between eyes, and 4 spines on each side of the carapace. (Oregon Department of Fish and Wildlife).

Identification. The Chinese mitten crab (*Eriocheir sinensis*) is named for the dense patches of hairs on the claws of larger juveniles and adults. Other characteristics include a notch between the eyes and a smooth, round carapace or body shape. The legs are also characteristic and are twice as long as the carapace width. The mitten crab is native to the coastal rivers and estuaries of the Yellow Sea in China. In California, the mitten crab was first collected in 1992 by commercial shrimp trawlers in South San Francisco Bay and has spread rapidly throughout the estuary and into areas in the Sacramento River drainage. Introduction to the estuary was either deliberate release to establish a fishery (the mitten crab is a delicacy in Asia) or accidental release via ballast water.

Ecology. The mitten crab is catadromous—adults reproduce in saltwater, and the offspring rear in freshwater. Mating and fertilization occur in late fall and winter, generally at salinities greater than 20 percent. The females carry their eggs until hatching, and both sexes die soon after reproduction. A single female can carry 250,000 to 1 million eggs. After hatching, larvae are planktonic for approximately 1 to 2 months. The small, juvenile crabs settle in salt or brackish water in late spring and migrate to freshwater to rear. Young, juvenile mitten crabs are found in tidal freshwater areas and usually burrow in banks and levees between the high and low tide marks. Mitten crabs apparently do not burrow as extensively in nontidal areas, probably because they are not subject to desiccation during low tides. Older juveniles are found further upstream than younger juveniles, often several hundred miles from the sea. Cues for this upstream migration are unclear, although high densities and the monsoon season have been identified as possible causes. Maturing crabs move from shallow areas to the channels in late summer and early fall and migrate to saltwater in late fall and early winter to complete the life cycle. Mitten crabs are adept walkers on land; in their upstream migration, they readily move across banks or levees to bypass obstructions such as dams or weirs.

Mitten crabs are omnivores, with juveniles eating mostly vegetation, but preying upon animals, especially small invertebrates, as they grow. Adult crabs have been accidentally caught by anglers using a variety of baits ranging from ghost shrimp to shad. Relatively little is known about the predators of the mitten crab, although white sturgeon, striped bass, bullfrogs, loons, and egrets have been reported to prey upon them. It is assumed that other predators, including largemouth bass and larger sunfishes, river otters, raccoons, and other wading birds will consume mitten crabs.

Impacts. The ecological impact of a large mitten crab population is the least understood of all impacts. Although juveniles primarily consume vegetation, they prey upon animals as they grow. A large population of mitten crabs could reduce native invertebrates through predation and change the structure of fresh and brackish water benthic invertebrate communities. There may be some direct competition between mitten crabs and other invertebrates for food and habitat. Banks and levees may be weakened in the presence of large numbers of the burrowing mitten crabs. This sort of damage has occurred in Germany, where burrows were reported to be up to 50 cm (20 in) deep. Mitten crabs that burrow are, on average, less than 40 millimeter (mm) carapace width; larger mitten crabs usually do not burrow but take cover under objects on the substrate or in deep pools. Although it is smaller crabs that are burrowing, large numbers of these crabs have the potential to cause bank damage over time. Burrowing removes sediment from the bank, weakening the overall structure. In addition, mitten crab burrows are designed to hold water at low tide. Water retained in the burrows increases the pore pressure on the banks, increasing the potential for bank slumping. Mitten crab burrow densities as high as 30/m2 (2.7/ft2) have been reported, with most burrows no more than 20 to 30 cm (8 to 12 in) deep. The

highest density of juvenile crabs was 6/m2 (0.8/ft2) in Suisun Marsh and 1/m2 (0.1/ft2) in the Delta in summer 1997. High densities of mitten crabs also interfere with pumping and fish salvage operations in California. Fish in salvage operations associated with screens face increased mortality caused by mitten crab presence. As mitten crabs migrate downstream in the fall, they can become entrained with the fish in these collecting facilities. When mitten crabs are abundant, they clog collection facilities and their sharp spines and legs damage and even kill many of the fish entrained with them.

Juvenile mitten crabs have been reported to damage rice crops by consuming the young rice shoots and burrowing in the rice field levees. Rice fields in tidally influenced areas apparently are most subject to damage.

Damage to commercial fishing nets and the catch when the crabs are caught in high numbers is the most widely reported damage. It may also be time consuming to remove crabs from the nets.

Mitten crabs may pose a health threat. The mitten crab is the secondary intermediate host for the Oriental lung fluke, with mammals, including humans, as the final host. Humans become infested by eating raw or poorly cooked mitten crabs. However, neither the lung fluke nor any of the freshwater snails that serve as the primary intermediate host for the fluke in Asia have been found in the United States.

5.2.2.2.1 Control methods

Crab control often takes advantage of the mitten crab's migratory behavior; traps are placed on the upstream side of dams to capture juvenile crabs as they migrate upstream. At one site, as many as 113,960 crabs were trapped in a single day. It was hypothesized that this population explosion may have coincided with a reduction of riverine fish predators. Recently, European mitten crab populations have stabilized, although there are occasional reports of "invasions." In 1981, mitten crab population in the Netherlands increased substantially, resulting in serious fishing net damage.
Attempts to screen Chinese mitten crabs from California pumping and fish salvage operations are being undertaken by Reclamation. A traveling screen, a type of conveyor-belt apparatus, has been tested for removal of mitten crabs and shown to be capable of removing 90 percent of crabs from collection areas.

5.2.3 Aquatic or semiaquatic biting flies

Although mosquitoes are the best known of the flies that bite humans, several other species can be locally important as a nuisance and can cause public health problems. All of the biting flies are blood feeders, and some are known to transmit diseases to humans and animals. The direct effects of bites to humans can

be painful (e.g., deer flies) and produce swelling and intense itching as the result of injected saliva (e.g., blackflies). The flies in this group all have aquatic life stages.

5.2.3.1 Blackfly (Simuliidae)

Identification. These insects belong to the family *Simuliidae*, classified in the order Diptera. The adult fly is a small, gnat-like insect that seldom is more than 0.47 cm (3/16 in) long, varying in color from gray-brown to black. The legless larvae are 0.2 to 4.5 mm (0.008 to 0.177 in) in length (depending on age), often black in color, with irregular mottling. Their general form is worm-like, but they are easily recognized because of certain structural features. The outline shape is very consistent, with a pair of large cephalic fans (used for filter feeding) on the head and two nearby prolegs. The bottom of the teardropped-shaped body is attached to submerged substrates with a posterior sucker. Pupae are about 0.5 mm (0.020 in) in length and are covered in a silken cocoon that remains on a substrate long after the fly has emerged.

Ecology. The "blackfly" or "buffalo gnat" is known for the persistent way in which the female pursues and bites warm-blooded animals, including humans. Known also as "turkey gnats," adult blackflies can be an annoyance and sometimes produce serious effects for humans and animals. Blackflies not only bite humans, but they also feed on birds and livestock. Domestic animals subject to mass attacks of blackflies may be killed in large numbers. In some countries, the blackfly is a health concern and a vector of human disease.

Adult blackflies are small, with a humpbacked appearance. All blackflies require running water for development and favor sites with rock surfaces (pebbles, small rocks, concrete) that are largely clear of silt. The blackfly larvae attach themselves to rocks or other submerged materials and feed on organic particles they filter from the passing waters.

Increased quantities of planktonic food items in reservoirs can result in abundant blackflies in downstream rivers or canals. Trailing vegetation or rotted aquatic plants also are attractive attachment sites for blackflies. Several generations can be produced each year. Adult insects can be present and produce problems for months.

The blackfly life cycle can be rapid, taking about 3 weeks to complete (period from egg laying to maturation of the adult). Only the female bites, drawing blood to provide protein for egg maturation. Adults live about 2 weeks. Two to four generations may be produced annually, and individual females may lay several hundred eggs.

Blackflies are day feeders but tend to show some periodicity. During sunny, warm days, peak attacks occur in mid-morning and then have a more intense phase in evening, ending at dusk. However, biting greatly intensifies at the onset of storms and may persist all day when overcast conditions occur.

Impacts. Blackflies can cause mortality in wildlife. In Wyoming, blackflies were responsible for mortality of red-tailed hawk nestlings. Impacts to nestlings included physical harassment, direct loss of blood and body fluids from biting flies, and infection with *Leucocytozoon* (a protozoon transmitted by blackflies). Anemia and infection have also been noted in commercial poultry operations. Species that attack birds feed mostly around the eyes, and the intense annoyance can cause animals to become greatly agitated and exhaust themselves in attempts to escape. Blackfly attacks on humans, cattle, horses, and pigs tend to be concentrated around the ears and head. In addition to the blood loss, effects of the insect saliva can cause swelling and intense skin irritation. Allergenic asthma, nausea, and more systemic effects can also occur, a condition known as "blackfly fever."

The importance of this insect on the hydraulics of irrigation systems involves the pupal encasements or cocoons that attach to submerged canal and flume linings. The slipper-shaped encasements produce extensive areas of roughened surfaces, resulting in increased resistance to canal flow. The cocoons are cemented firmly to the substrate and may be in the shape of a pocket, slipper, or vase. The pupal cases are quite persistent following emergence of the adult insects and often require mechanical removal from canal linings.

Blackflies are vectors of a human disease (onchocerciasis) that causes river blindness via transmission of a microscopic worm in parts of Latin America, Yemen, and Africa.

5.2.3.1.1 Control methods

Reduction in blackfly populations is possible where chronic problems occur and larval rearing areas are known. This involves metering of Bacillus thuringiensis var. israelensis into the flowing water where larvae occur. Increased doses may be required during algal blooms. Trade names include Bactimos® and Vectobac®, the same products used for larval control of mosquitoes. Waterflow regulation has large impacts on the larval stages and can result in increased or decreased larval populations. Flow manipulations in canals may be an effective control method if flows can be decreased during times critical to larval development. Adult control is problematic, due to the migratory behavior of the insects. It is likely that permethrin-based products are among the best, as these are effective against most fly species and are labeled for use in mosquito control and for fly control of livestock.

In terms of personal protection, choice of clothing can be important. Blackflies are highly attracted to dark colors and less attracted to light colors. Hats (light colored) that cover the ears are an important precaution. The repellent N, N-diethyl-m-toluamide (DEET) is somewhat effective for prevention of blackfly bites, although swarming gnats may still be an annoyance even when using repellent.

5.2.3.2 Deer flies (Tabanidae)

Identification. Deer flies (*Chrysops* spp., *Silvius* spp.) are moderate-sized insects. Most common species are gray or light brown, sometimes with patterned bodies and wings, and have large, colored eyes. Deer flies are day biters, produce a painful bite, and frequently draw blood in the process.

Ecology. Eggs are laid on grasses and other aquatic vegetation around the edge of small ponds and other permanent standing water. The larvae develop within the mud and plant matter around the edge of the pond, feeding on decaying organic matter and small invertebrates. Deer flies have a 1-year life cycle. Adults are present for a period of 2 to 3 weeks and rest on shrubbery or tall grass when not mating and feeding.

Horse flies are closely related, but they are somewhat larger than deer flies and generally have similar habits.

5.2.3.2.1 Control methods

There are no chemical controls for deer fly larvae, which develop in mud around edges of ponds and small streams. Populations can be suppressed by managing vegetation around ponds to inhibit egglaying. This may be achieved by removing vegetation in the immediate vicinity of the pond edge.

Insecticides may be used to control adults and should be directed at shrubbery and other resting sites. Deer flies and horse flies may also be trapped. The "Manitoba trap" uses a dark, heat-absorbing body to attract these insects, which then are directed to fly into a cone where they are trapped. A typical design for such a trap includes a dark painted beach ball or similar object suspended under a cone. The addition of small amounts of CO_2 around the trap can further increase the attractiveness of the trap. DEET and other insect repellents are not very effective at deterring deer fly bites. “Trolling” may be an effective way to control adult deer flies by taking advantage of their behavior of attacking around the head and shoulders of people. Traps can be mounted on tractors or lawnmowers and are made of nursery flower pots that are painted bright blue and covered with Tanglefoot®. Traps can also be designed and built for individual people.

5.2.3.3 Mosquitoes (Culicidae)

Reclamation structures may create mosquito habitat from seepage along canals or in some reservoirs. Biting mosquitoes can become a serious nuisance to people recreating in infested areas. They may also be a health concern where disease agents, which are often maintained in bird populations, are transmitted from mosquitoes to humans.

Mosquitoes also serve a vital ecological function. The larvae, pupae, and adults are important as food for fish, birds, bats, frogs, and insects—an essential consideration when the subject of mosquito control arises. Successful mosquito management is both an art and science. Field training is needed to properly sample and control mosquito populations. Whenever possible, refer mosquito management to experienced and qualified personnel.

Identification. While there are more than 13 genera of mosquitoes in the United States, most pest mosquitoes belong to one of three: *Anopheles*, *Aedes*, or *Culex*.

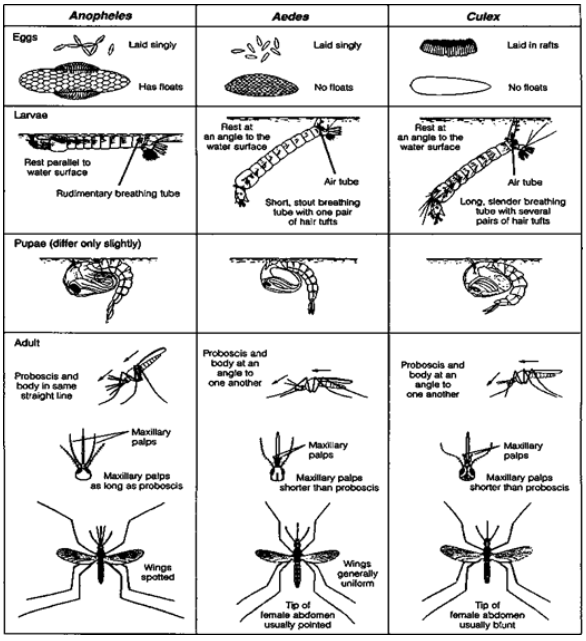

Figure 5.2.3.3.—Main characteristics for discriminating *Anopheles*, *Aedes*, and *Culex* species of mosquito (World Health Organization).

Anopheles mosquitoes breed in semi-permanent to permanent bodies of freshwater. They prefer water with abundant aquatic plants that provide protection from fish and other predators. Eggs, supported by floats on each side, are laid singly on the surface of the water.

Anopheles mosquitoes can be distinguished from *Aedes* and *Culex* mosquitoes in several ways: (1) *Anopheles* have patterned wings; (2) adult *Anopheles* females have palps that are almost as long as their proboscis; (3) adults rest on surfaces

with their head lower than the abdomen, while *Aedes* and *Culex* species rest with the head and abdomen parallel to the surface; and (4) the *Anopheles* larvae float parallel to the water surface rather than hanging down at an angle.

Some *Aedes* mosquitoes are called "floodwater mosquitoes" because they lay their eggs singly on damp soil or vegetation in areas that are periodically wet. There are also *Aedes* species that lay their eggs in artificial containers or tree holes. Eggs can remain dormant until they are flooded and conditions are favorable for hatching. Salt marsh species breed in coastal marshes that are occasionally flooded by high tides. Many floodwater and salt marsh species can fly great distances (8 to 32 kilometers [km]); 5 to 20 miles (mi) from their hatch site.

The Asian tiger mosquito, *Aedes albopictus*, first appeared in the United States in 1985. Its rapid spread is of concern because it is known as a disease-carrying mosquito in its native Asia. It also breeds readily in water-filled containers, a breeding site that is commonly available.

Culex mosquitoes breed in quiet, standing water of all types, ranging from containers to large pools. *Culex* prefer polluted, standing water with a large amount of organic material. Eggs are laid on the surface in "rafts," of 100 or more eggs. While adult female *Aedes* and *Anopheles* mosquitoes have a pointed tip at the end of the abdomen, *Culex* mosquitoes have a blunt tip.

Ecology. Mosquitoes belong to the insect order *Diptera*. Mosquito mouth parts form a long piercing-sucking proboscis with which females obtain a blood meal needed for egg production. Nectar is the main food source for male mosquitoes. Four distinct stages make up the life cycle of the mosquito: egg, larva, pupa, and adult. Larval and pupal stages are typically aquatic.

Eggs laid on the water's surface hatch in 1 to 3 days. Eggs laid by *Aedes* mosquitoes above the water line remain dormant until they are flooded. Larvae float at the water’s surface breathing through an air tube and feeding. When disturbed, they dive towards the bottom with a jerking motion. The larval stage lasts from 5 days to several weeks, depending on the species and on environmental conditions such as water temperature. The larvae transform into pupae. Pupae don't feed, but they are quite active and may be seen breathing at the surface or bobbing through the water. The adult mosquito develops inside the pupal skin and will emerge in 2 to 3 days. Mosquitoes pass the winter either as eggs or adults.

Only the female mosquito needs a blood meal for egg production. This blood-feeding habit results in the ability for mosquitoes to be disease vectors. Adult male mosquitoes feed only on plant nectar and are harmless to people. Most mosquitoes feed just after dark and again just before daylight. They spend the daylight hours resting in dark, damp areas. Some mosquito species, however, are daytime feeders, while others may feed during both day and night. Larval

mosquitoes feed on organic debris (with the exception of a few species that are predators). They use a pair of mouth brushes to strain out small aquatic organisms and particles of plant and animal material present in the water.

Mosquitoes may breed and develop any time from the beginning of spring to the first hard frost of fall. In general, populations are highest in summer and early fall. There may be from one to several generations of mosquitoes during a season, depending on the species, the temperature, and the amount of rainfall. When rainfall is abundant, many species can lay eggs continuously. Under ideal conditions with high temperatures, development can be completed in less than a week, resulting in large populations of flying adults.

Impacts. Worldwide, mosquitoes transmit many debilitating and fatal diseases, especially in tropical, developing countries. The most important of these is malaria, which has been on the increase in the last decade. In the United States, mosquitoes are primarily an annoyance, causing itching bites and welts that can become secondarily infected. The association of dams with mosquito and human health problems has been broadly recognized. Human mosquito-transmitted diseases remain relatively rare, due largely to modern pest control methods and disease detection. Encephalitis, West Nile Virus (WNV), and dog heartworm, among dogs, are the main diseases transmitted in the United States.

At least six major types of mosquito-transmitted encephalitis occur in the United States. These are eastern equine encephalitis, western equine encephalitis, California encephalitis, St. Louis encephalitis, Venezuelan equine encephalitis, and La Crosse encephalitis. Each type is caused by a different virus or virus complex affecting the central nervous system. These viruses are normally transmitted by mosquitoes from birds or small mammals. Occasionally horses or humans are infected. Despite the small number of people infected annually by eastern equine encephalitis, it is considered a serious disease because it is often fatal.

West Nile Virus (WNV) is a typically mosquito-borne virus indigenous to Africa, Asia, Europe, and Australia. WNV was recently introduced to North America and first detected in 1999 in New York City. The virus spread across the United States by 2002. The virus is maintained in nature in a mosquito-bird-mosquito transmission cycle primarily involving Culex spp. mosquitoes. A large number of birds can become infected with WNV. Most survive, with highest mortality rates in passerines as shown in laboratory studies. Members of the crow family (*Corvideae*) are the most susceptible to death from WNV.

In the United States, most human infections with WNV occur in summer or early fall and coincide with high abundance of adult *Culex* mosquitoes. Mosquito feeding preferences can increase or decrease the potential of mosquitoes for transmitting the virus to humans. Opportunistic feeders that feed on both mammals and birds are best for bridging WNV from birds to humans and other

mammals. Having a suite of *Culex* species is important for maintaining and bridging WNV in wetland ecosystems in California. Transmission of WNV is most intense when initially arriving in a geographic area. WNV will decline to a lower level after susceptible wild birds have died or recovered and developed immunity. Transmission of WNV to humans requires a reservoir of infected, viremic animals (mostly birds) from which mosquitoes carry the virus to people. To prevent WNV infection in humans, extensive early season larval control has been recommended to prevent the buildup of mosquito populations.

Dog heartworm is a filarial parasitic disease transmitted by different mosquitoes to dogs and, rarely, man. Once a problem only in coastal areas, dog heartworm is now found in every State in the United States. The nematodes, which lodge and grow in the heart tissue, can be fatal to dogs if left untreated. This disease is now treatable with veterinarian prescribed medication.

5.2.3.3.1 Monitoring and thresholds

Sampling and counting the mosquito population helps determine whether control is necessary; what growth stage the mosquitoes are in (information necessary to time control methods); which mosquito species are present, especially important in areas of disease outbreaks; and, finally, it helps to gauge how effective control efforts have been and when they need to be employed again. Sampling should be done weekly and at the same sites each time. The numbers counted, the growth stage, and the species and sex should be recorded when possible. This information gives an estimate of the population and must be compared with previous counts to determine whether the number of mosquitoes is increasing or decreasing. An IPM practitioner can get an estimate of the number of mosquitoes in an area by counts of larvae or adults or both.

Larval dipper counts. A larval dipper can be purchased through biological supply houses, or you can make your own. It is basically a shallow, plastic, enamel, or aluminum cup attached to a long handle. To collect floating mosquito larvae and pupae, depress one end of the dipper under the surface and quickly but smoothly scoop up larvae. If you move too quickly or cast a shadow on the surface, larvae and pupae will dive to the bottom to escape.

The number of dips at each site will vary according to the size of the water body, but generally is in multiples of ten. Take five dips from open water and five from the water's edge, near vegetation if possible. Dipper inspections should be made weekly during the breeding season. Larvae can also breed in rainwater collected in containers such as buckets, garbage cans, canoes, tires, and animal watering troughs. To sample larvae in less accessible areas, such as tree holes, use a large basting syringe. Empty them into a white pan for counting. One advantage to sampling larvae is that the problem can be treated at the same time it is identified. Adult counts do not necessarily indicate mosquito sources, since they can fly in from some distance away.

Adult trapping. Trapping of adult mosquitoes gives information on the relative population size and the species composition. Light traps are useful for monitoring certain species of mosquitoes. Not all species are attracted to lights. Different models of traps vary in the numbers, the species, and the proportion of males to females that they catch. New Jersey light traps and Center for Disease Control light traps (and their variations) are commonly used. Light traps are operated from dusk to dawn, powered either by electric line or a battery. Some traps are available with a photoelectric cell that turns the light on at dusk and off at dawn. When mosquitoes approach the light, they are blown by a small fan down through a funnel into a killing bag or jar.

The light trap should be hung about 1.8 m (6 ft) off the ground in an open area near trees or shrubs but away from competing lights and buildings. Traps should be emptied each morning, and the catch should be stored in a labeled box until it can be sorted and identified. Since mosquitoes are attracted to carbon dioxide in the host's breath, some light traps are augmented with a 0.45-kilogram (kg) [1-pound (lb)] block of dry ice, wrapped in newspaper and hung next to the trap. The addition of dry ice also allows sampling on moonlit nights or in areas where bright lights may conflict with the light trap. It also allows daytime sampling of species that are active during the day or that are not attracted to lights. Because some species are not attracted to light traps, they should be used in conjunction with other kinds of sampling methods. Monitoring for adult mosquitoes is an important part of the management of some mosquito-vectored diseases such as equine encephalitis. The decision to use pesticides for mosquito suppression is made only after intensive monitoring of the mosquito population in an area to determine if the species that vectors the disease to humans is present. The incidence of the disease in the wild animal population is monitored as a way to estimate the possibility of transmission to humans. Visitor education is also emphasized to alert people to the presence of the disease and instruct them on how to protect themselves.

Threshold/action population level. Data from sampling and monitoring will be used to help decide at which infestation level to initiate management tactics. This decision level will be based on larval and adult counts, complaints from visitors, the potential for disease outbreaks, and the risk of the management tactics to other animals. For instance, in an area where there have been encephalitis cases, the risk is higher and the action level will be lower than in other areas. The number and location of visitor or neighbor complaints should be plotted on a graph against the counts of aquatic forms and adults for the same date and site.
The amount of unacceptable complaints is the injury level. The graph should show the number of mosquitoes that correspond to the complaint injury level. This is the action level. Action levels are different for each situation. In some areas, general annoyance does not occur until the number of female mosquitoes caught in light traps exceeds 25 per night. Other action levels that have been used are dipper counts averaging five larvae per dip.

5.2.3.3.2 Control methods

The key factor in a mosquito IPM program is determining whether control is necessary. This decision requires a sampling program to determine what species are present and in what numbers, and a set of action thresholds to determine if management tactics are necessary. If control is needed, then decisions must be made on the best combination of tactics to suppress the mosquito population, while affecting the environment as little as possible.
Normally, source reduction by eliminating or altering the water, so mosquitoes cannot breed or complete their life cycle, is the first choice for control. If source reduction is impossible or incomplete, the next tactic to consider should be biological control of the larvae with predators, bacterial insecticides, or growth regulators. Visitor education also represents an essential part of a mosquito IPM program. Interpretive displays can be used to explain the role of mosquitoes as a food source for animals such as bats, birds, and fish, and to help visitors understand that not all mosquitoes bite or carry disease. Personal protection through the use of proper clothing and repellents can be explained, as well as the avoidance of areas with high mosquito populations.

Source Reduction. Along with monitoring of populations and application of approved pesticides when a nuisance threshold is reached, other source reduction recommendations include: (1) implementation of an effective water-level management scheme; (2) maintenance of effective internal drainage; (3) control of marginal vegetation; and (4) operation of dewatering projects for mosquito control. Dewatering areas controls mosquito production in the spring and summer. Water level management destroys mosquito eggs and larvae by stranding them onshore or drawing them into open water, where they are exposed to predators. Reservoir drawdowns during the summer and fall of at least 6 m (20 ft) were effective in providing mosquito control in reservoirs by decreasing marginal vegetation. Mosquito production is often highest in shallow, stagnant waters with dense, emergent vegetation.

Windswept shorelines lacking vegetation, and pools containing fish and other mosquito larvivores, are not conducive to mosquito production.

Source reduction controls the immature mosquito stages—eggs, larvae, and pupae. Because these stages are concentrated in discreet bodies of water, they are much easier to control than are dispersed adult mosquitoes. Two water management tactics are ditching and ponding. These tactics are only allowed in a developed zone. Ditching controls mosquitoes in two ways. In some cases, water drains out of the potential breeding sites. In others, ditching allows fish access to the isolated pools, where they prey upon the larvae and pupae. Ponding is another water management tactic that turns a temporary pool breeding mosquitoes into a permanent one capable of supporting fish and other mosquito predators. Ponding is accomplished by raising the water level, digging new pools, or impounding water.

If standing water can't be eliminated, control of mosquito larvae in the water is the next step. This is best done with natural controls such as mosquitofish or biorational insecticides. The latter do not affect pupae and should not be used if this is the predominant life stage.

Biological Controls. Fish are among the most important predators of mosquito immatures. Mosquitoes are rarely a problem in a body of water that also contains fish. To use fish as a biocontrol agent, the water must be deep enough and must have the right combination of environmental conditions to sustain fish. Introduced fish must have protection from native fish and other aquatic predators. The mosquitofish, *Gambusia affinis*, is often reared and released to control mosquitoes. However, this fish tends to outcompete native fish if not managed with care. Some Reclamation regions are discouraging use of mosquitofish in bodies of water that may have native fish or amphibians. Native fish may also be used to control mosquito larvae.

Various commercial products containing *Bacillus thuringiensis israelensis* (B.t.i.) are available for treating bodies of water. These products kill mosquito and blackfly larvae. It is nonhazardous to humans, other animals, fish, and predacious insects. B.t.i. is available as granules, slow release briquettes, or wettable powder. It can be applied by hand, with a backpack blower or granule spreader, or by aircraft. Because the released bacterial spores must be ingested by the larvae, B.t.i. is not effective against eggs, pupae (which do not feed), or mature larvae that are ready to pupate and have stopped feeding.

Mosquito larvae are an important food source. Large numbers fall prey to fish, insects, and spiders. Naturally occurring bacteria, protozoa, fungi, and nematodes also kill mosquito larvae. Both bacteria and predatory fish have been used as biocontrol agents to control mosquito larvae. Birds, bats, frogs, lizards, spiders, and insects feed on adult mosquitoes.

Chemical Controls. Insect growth regulators, such as methoprene, do not kill the larvae but prevent them from developing into adults. Timing of application is important, since only mature larvae are affected. Larvae that have already pupated will continue to develop into biting mosquitoes. Methoprene can be applied as slow-release briquettes, granulars, or ground or aerial spray. Most insect growth regulators do not harm other nontarget species. Since methoprene does not kill the immatures, larvae and pupae will still be found in dip counts. The only way to determine whether the treatment was effective is to rear the collected larvae and pupae and observe whether they develop into adults.

Petroleum oils or specialized mineral oils can be applied to the water. The oil forms a thin film over the surface which suffocates eggs, larvae, and pupae. In the presence of wind, waves, or rain, the oil film breaks up and is less effective. Some oils are toxic to fish, other organisms, and aquatic plants.

Various insecticides can be applied to the water as dusts, granular, wettable powders, or emulsions. Consult your regional IPM coordinator for specific recommendations for your area. Pesticides will likely kill other aquatic insects and may be harmful to fish, birds, and mammals.

Adulticiding is space spraying for adult mosquitoes with insecticides. With an effective source reduction and larvaciding program, adulticiding should not be necessary. It is generally the last resort in an integrated mosquito control program, since spraying of adult mosquitoes provides only temporary relief. It must be repeated frequently to intercept new mosquitoes moving into the area. Adulticiding may be the only feasible management strategy in a natural area where mosquitoes pose a public health risk, since source reduction is prohibited.

Most adulticiding is accomplished with a truck-mounted, ultra-low volume sprayer. Depending on the area to be controlled, other application methods include a backpack or power sprayer, mist blower, thermal fogger, or application from aircraft. Spraying is usually done in early evening when winds are less than 9.6 km per hour (6 miles per hour). Ground spraying is not possible in most natural areas.

Personal insect repellents containing N, N-diethyl-m- toluamide (DEET) applied to skin or clothing provide protection from biting. Another repellent, permethrin, may be used on clothing only. Jackets and tents impregnated with repellents are also available.

Other Controls. Screening of doors, windows, and vents is a time-honored method of keeping mosquitoes out of structures. Ordinary window screen of 16 by 16 or 14 by 18 meshes to the inch will keep out most mosquitoes. Campers can hang mosquito netting over cots, tent openings, picnic tables, etc. Long sleeves, long pants, hats, and veils give additional protection from mosquitoes.

Insect electrocuters, or "bug zappers," do not effectively control mosquitoes. Many mosquitoes are not attracted to the light. Tests in residential areas have shown that only a tiny percentage (usually less than 3 percent) of the insects killed are mosquitoes. Most are harmless gnats, moths, and beetles, or beneficial preadators.

5.3 Organisms associated with closed systems

This section describes organisms that can impact closed systems such as wells, pipes, tunnels, and dam drains. These systems, which often have small diameters, may be especially susceptible to reduction in flow capacity via clogging.

A number of other organisms including bacteria, fungi, worms, crustacea, protozoa, bryozoans, and rotifers are often found attached to the walls of closed

systems. These organisms, often microscopic, are often found growing and living in an association that has a brown to gray color and a mat-like appearance. Encrustations of this type ranged from 0.32 to 0.63 cm (1/8 to 1/4 in) thick from a tunnel on the Colorado-Big Thompson Project. It was found to contain organisms belonging to the aforementioned groups. The dried encrustation was analyzed and found to contain 8.8 percent ferric oxide and 8.7 percent manganese oxide.

Copper, sodium, calcium, aluminum, magnesium, and silica were also found in the dried sample. The filamentous bacteria observed in the sample were probably responsible for the high content of iron and manganese found in the encrusted material. Certain bacteria oxidize these elements in utilization as an energy source, resulting in the formation of insoluble compounds deposited in the encrustation. In some cases, larger organisms such as midges and clams may colonize substrates in closed systems.

5.3.1 Effects of pipe growths on closed systems

The organisms described above are capable of capacity reduction of conduit and plugging of various structures, particularly small diameter pipes and orifices in closed systems that are used for delivering irrigation or municipal/industrial water in multiple-use water systems.

Although pipe growths have caused relatively few reported or recognized problems on irrigation projects to date, it is reasonable to assume that the problems will increase with an anticipated increase of construction of closed systems. Also, a trend toward enriched surface waters in the form of nutrients will increase the biological productivity of the water, which will increase the food supply for the growth of the animals. The hydraulic problems caused by these growths could be kept to a minimum by designing new closed systems that use high-velocity flows and have smooth surfaces, and by elimination of structures, small pipes, and other facilities prone to clogging. Structures should be observed for growths of the types described in this discussion. Any growths found should be kept under surveillance to determine whether the infestation will develop into a major problem.

5.3.2 Control of pipe growths

Not much information is available concerning the control of the organisms described. Various mechanical devices that use scraping and brushing techniques have been used to dislodge the attached organisms. Chlorine is probably the most frequently used chemical agent for control, where permitted. Other possible chemical control agents include steam, hydrogen peroxide, and ozone, again where permitted. Emulsified xylene aquatic weed herbicide has proven effective on clams and bryozoans in a few applications. Copper sulfate has also been

reported effective on certain of these organisms. Midges may be controlled with B.t.i.. In addition, control of plankton food supply by reducing the level of nutrient enrichment of water or algaecides might reduce populations of these animals. Any control method employed will need to be developed and applied on schedule in much the same manner as in developing good weed control programs.

5.3.3 Iron bacteria

Iron bacteria occur naturally in iron springs, streams, water delivery lines, wells, and dam drainage. They utilize ferrous iron from plumbing systems and natural origins as an energy source, oxidizing it to ferric hydroxide (Fe(OH)3), a rusty precipitate. Presence of iron bacteria is typified by these rusty precipitates and abundant cottony flocculent materials (empty colonial sheaths). Neglect may eventually lead to loss of the function of such systems. Iron bacteria are most detrimental to water wells, dam drainage networks, and agricultural field drainage systems. In these sites, they can produce large amounts of biomass that clogs screens, geomembranes, and interstitial spaces in the sands of the drainage medium. In water wells, iron bacteria cause blockage, corrosion, taste and odor problems, and reduce the capacity and service life of the well. In some cases, well production has been reduced by 50 percent by iron bacteria. In dam drainage networks, flows from drains have been reduced by 50 percent or more. Blockage of dam drainage could lead to unregulated water levels within the edifice and result in structural damage and possibly failure of the dam. In agricultural drainage systems, blockage by iron bacteria can lead to elevated ground water and loss of the ability to remove dissolved salts, which may lead to crop damage and failure.

5.4 Terrestrial invertebrates

5.4.1 Arthropods

5.4.1.1 Fire ants (Solenopsis spp.)

Fire ants are aggressive, swarming ants that inject venom from a wasp-like sting. These burning stings are followed by tiny, itching pustules. Recreation areas infested with fire ants may lie abandoned and unused. Fire ant mounds interfere with farming and mowing operations and turn recreational fields into disfigured moonscapes. Fire ants have caused sections of roads to collapse by removing soil from under the asphalt.

Fire ants are also found nesting in human structures and can be found in wall voids, around plumbing, and under carpeting. The ants have also been found invading outdoor electrical equipment, as they are apparently attracted to the electrical fields. Infested sites include household electric meters, traffic signal

control boxes, and even airport runway lights. Fire ants are voracious predators and sometimes feed on pests such as boll weevils, sugarcane borer, ticks, and cockroaches. The imported fire ant is thought to have dramatically reduced the range of the lone star tick, a serious livestock pest.

Identification. There are many species of fire ants in the United States, but four of the most serious pests are in the genus *Solenopsis*: the red imported fire ant, black imported fire ant, the southern fire ant, and the fire ant. Distinguishing between species of fire ant is difficult, even for experts. Identification usually requires 40 or more randomly collected worker ants for study. The following sections describe the four fire ants of major concern.

The red imported fire ant (*Solenopsis invicta*) was introduced from South America and becomes the number one fire ant pest wherever it occurs. This species is associated with disturbed habitats, mostly created by humans, and is abundant in old fields, pastures, lawns, roadsides, and many other open, sunny areas. It often inhabits fields used for agricultural purposes, where its large, above-ground mounds create problems in planting and harvesting crops. In areas where grass is periodically cut, mounds are flush with the ground and are hard to see. This species is rarely found in mature forests and other areas with heavy shade, unless part of the area has been disturbed by fire or storms.

The red imported fire ant builds mounds that are, on average, 25 to 61 cm (10 to 24 inches) in diameter and 46 cm (18 inches) high. Larger mounds are not uncommon, and they also may extend 1.8 m (6 ft) underground. The primary function of mounds, beyond that of the simple ground nests of other ants, is microclimate regulation—controlling the temperature and humidity. The ants can maintain a higher temperature inside the mound than outside, allowing them to continue colony growth during cool weather.

Mounds are made from the excavated soil, are often rich in organic materials, and contain interconnected galleries and chambers. The soil below ground also contains galleries and chambers. Newly established nests develop rapidly, and winged adults capable of reproduction are produced for most of the year.

(8-10 months), much longer than native species. Red imported fire ants quickly spread through a suitable habitat, and the species is now found throughout most of the Southeastern United States and west into Texas.
The black imported fire ant, *Solenopsis richteri*, is very similar to the red imported fire ant. It is currently limited to a small area of northern Mississippi and Alabama. It may be displaced from established habitats by the red fire ant. The black imported fire and is not currently known to occur found Reclamation boundaries.

Scientists have long thought that the black and red fire ants were two distinct species. Recently, it has been discovered that hybrids of these ants produce viable offspring, and some scientists now wonder whether they are simply two races of the same species that vary in color and perhaps behavior.

The southern fire ant, *Solenopsis xyloni*, is a native species that occurs from North Carolina south to northern Florida, along the Gulf Coast, and west to California. Colonies may be observed as mounds or, more commonly, may be constructed under the cover of stones, boards, and other objects or at the base of plants. These ants also nest in wood or the masonry of houses, especially around heat sources such as fireplaces. Nests often consist of loose soil with many craters scattered over 0.6 to 1.2 m^2 (2 to 4 ft^2). In dry areas, nests may be along streams, arroyos, and other shaded locations where soil moisture is high. Southern fire ants usually swarm in late spring or summer.

The fire ant, *Solenopsis geminata*, is a native species sometimes called the tropical fire ant. This ant ranges from South Carolina to Florida and west to Texas. Very similar to the southern fire ant, it usually nests in mounds constructed around clumps of vegetation, but it may also nest under objects or in rotting wood.

Ecology. Life cycles of the four fire ant species discussed above are very similar. Ants begin life as an egg, which hatches into a grub-like, whitish in color, larva. The larva is specialized for feeding and growing, and almost all growth occurs during this period. As with all insects, growth is accomplished by periodic molting, or shedding of the cuticle (skin). Having reached its final size, the larva becomes a pupa, in which various adult structures, such as legs, and in some cases wings, become apparent for the first time. Adults consist of queens and kings that are capable of reproduction and sterile workers.

The social unit of fire ants is the colony. Colonies, like individuals, pass through a characteristic life cycle. Fire ants are very typical of ants in general. In addition to workers and a queen, mature colonies contain males and females capable of flight and reproduction. These individuals are generally called "reproductives." On a warm day, usually 1 or 2 days following a rain, the workers open holes in the nest through which the reproductives exit for a mating flight. Mating takes place 91 to 244 m (300 to 800 ft) in the air. Mated females descend to the ground, break off their wings, and search for a place to dig the founding nest, a vertical tunnel 5 to 13 cm (2 to 5 inches) deep. They seal themselves off in this founding nest to lay eggs and to rear their first brood of workers. During this period, they do not feed utilizing reserves stored in their bodies. The first worker brood takes about 1 month to develop; these are the smallest individuals in the entire colony cycle. They open the nest, begin to forage for food, rear more workers, and care for the queens. Hereafter, queens essentially become egg-laying machines, each producing up to 1,500 eggs per day.

Multiple queen colonies are fairly common. A single colony may have 10 to 100 or more queens, each reproducing. Multiple queen colonies can mean up to 10 times more mounds per acre. The queens generally mate several times and may live for several years. Workers are less long lived and usually will not survive an entire season. As the colony grows, the original vertical tunnel is altered into multiple passages and chambers. Colony maturity is attained when reproductives are once again produced. The reproductives leave to mate and form new colonies. A mature colony of red imported fire ants can produce as many as 4,500 reproductives during the year in 6 to 10 mating flights between spring and fall. Nearly 2,500 queens may be produced per hectare (ha) (6,200 queens per acre) in heavily infested land, but mortality rates, mostly from predators, can reach 99 percent.

Colonies of red and black imported fire ants become territorial as they grow; they defend an area against all other fire ants. Therefore, fire ant colony populations often reach an upper limit, depending on the territory size of mature colonies. A typical figure for pasture land seems to be about 50 to 120 mounds per ha (20 to 50 mounds per acre) in single queen nests and up to 250 mounds or more in multiple queen nests. Mature colonies of imported red fire ants consist of an average of 80,000 workers, but colonies of up to 240,000 and more have been reported.

Colony workers leave the nest to search for food. They explore 15 to 30 m (50 to 100 ft) from the nest with an efficient looping pattern. Although the worker ants can chew and cut with their mandibles, they can only swallow liquids. When they encounter liquid food in the field, they swallow it and carry it back to the nest. Solid food is cut to reasonable size and carried back to the nest.

Food is shared with nest mates by regurgitating it so that it can be licked or sucked by other ants. In this way, most ants in the nest get fed equally. This food sharing is also why baits can be an effective control tactic against fire ants. Fire ant workers are attracted to oily or greasy foods.

Impacts. In infested areas, fire ant stings occur more frequently than bee, wasp, hornet, and yellow jacket stings. Stepping on a mound is almost unavoidable when walking in heavily infested areas. Furthermore, many mounds are not easily seen, with many lateral tunnels extending several feet away from the mound just beneath the soil surface. Ants defend these tunnels as part of their mound.

A person who stands on a mound or one of its tunnels, or who leans against a fencepost included in the defended area, can have hundreds of ants rush out to attack. Typically, the ants can be swarming on a person for 10 or more seconds before they grab the skin with their mandibles, double over their abdomens, and inject their stingers. Although a single fire ant sting hurts less than a bee or wasp sting, the effect of multiple stings is striking. Multiple stings are common, not only because hundreds of ants may have attacked, but because individual ants can administer several stings. Each sting usually results in the formation of a pustule

within 6 to 24 hours. The majority of stings are uncomplicated, but secondary infections may occur if the pustule is broken, and scars may last for several months. Severe infections requiring skin grafting or amputation have been known to occur. Some people experience a generalized allergic reaction to a fire ant sting. The reaction can include hives, swelling, nausea, vomiting, and shock.

People exhibiting these symptoms after being stung by fire ants should get medical attention immediately. Death can occur in hypersensitive people. Individuals who are allergic to fire ant toxins may consider desensitization therapy. An important indirect effect of the presence of fire ants is fear of being stung. Fear and anxiety about fire ants may limit the use of sites where fire ants are present by visitors and personnel alike.

5.4.1.1.1 Monitoring and thresholds

Monitoring. The first step is to identify the species of fire ants in the area. Infestation level generally consists of determining the number of active mounds in a particular unit area. Any mound where at least three ants are observed after mound disturbance should be considered active. Heavily infested fields can contain over 247 mounds per ha (100 active mounds per acre).

Another method of estimating ant populations for comparison studies is by collecting ants attracted at baits in a test area. A small piece of hamburger and a small piece of agar containing 40 percent honey are each placed on a small piece of aluminum foil or in a small plastic cup. The two baits are placed on the ground at each bait station, 0.3 to 0.9 m (1 to 3 ft) apart. Bait stations are placed about 9 m (10 yards) apart. The number of ants attracted to the baits per unit time is determined.

Threshold/Action Population Levels. The threshold population levels for fire ants will vary according to the species and the sites. In certain camping and recreational areas, for example, very few active mounds per unit area would likely be tolerated, particularly of the imported species. In contrast, a few active mounds per unit area probably would be acceptable in other types of sites; little- used hiking areas, for example. Every effort should be made to correlate fire ant populations observed through the use of monitoring techniques with complaints received from visitors and personnel. In this way, a complaint threshold level can be established for each site.
In areas where fire ants are not causing any problems, the best solution may be to do nothing. Some sites will only support a limited number of fire ants. These may be in the form of a few large colonies or many small ones. Established mounds defend territories, preventing the establishment of new colonies.

Maintaining several large, and perhaps well-marked, colonies may be a sound way to stabilize fire ant populations in an area, as long as there is a low risk of people or pets stumbling into the nest. Some researchers believe it may be best to selectively control fire ant colonies, allowing native species to flourish as a way to

prevent the introduction of the imported species, or leaving single queen imports alone to prevent the area from invasion by a multiple-queen "supercolony." Mounds built by fire ants in fields often interfere with mowing and farming operations. Not only is equipment damaged by dried and hardened fire ant mounds, but operators may refuse to enter fields infested by ants. The number of mounds per hectare that can be tolerated in regard to equipment damage must be determined case by case.

5.4.1.1.2 Control

Fire ants, particularly red and black imported fire ants, pose a serious dilemma on frequently visited public lands. Fire ant management consists of determining the species in the area, how extensive the infestation and damage is, the risk that visitors or personnel will be stung, whether control action is justified, and what the best strategies of control are.

Visitors and personnel should be directed away from infested areas and encouraged to observe proper sanitation procedures, so that fire ants are not attracted to recreational sites. Mechanical and other nonchemical control measures should be considered first if control is deemed necessary. Remember that control may not be necessary in many cases. When it is necessary, chemical control, particularly the use of baits, may be attempted if other control measures have failed and Reclamation has approved the use of pesticides.

Mechanical Control. Mounds can be dug up and moved or destroyed, but not without some risk that the fire ants will successfully attack the digger. Dragging or knocking down mounds may provide a limited level of control, but only if mounds are dragged just before the first hard freeze. Mounds are destroyed by pulling a steel I-beam drag, weighing about a ton, behind a tractor across the ant-infested area. Destroying mounds during the warm season will not reduce the number of active mounds; ants quickly rebuild their nests. A number of mechanical mound pulverizers, ant electrocuters, even nest exploders, have been developed for fire ant control, but so far the effectiveness and practicality of these devices are open to question.

Boiling water has been added to individual mounds with varying degrees of success reported. Approximately 11 liters (L) (3 gallons [gal]) of hot water poured into each mound will eliminate about 60 percent of the mounds treated. This technique should only be used after rain has fallen and fresh mounds have been built. During these times, ants are at shallow depths and can be impacted by the hot water. Surviving mounds will need to be treated again. Water has also been applied as steam, using a steam generator, usually on a cool day. Both techniques are cumbersome in the field, especially where large numbers of mounds are involved. Area-wide flooding or prescribed burning of fire-ant- infested areas has proved ineffective and may promote the establishment of new colonies.

Cultural Control. The most effective measure for preventing injury to visitors and personnel is education. Visitor activities should be directed away from highly infested areas. Visitors should be informed about the habits of fire ants, how to recognize them, and how to avoid them. Visitors should be encouraged to use proper sanitation, so that fire ants are not attracted to such sites as picnic areas; and if the worst happens, information should be available on what to do if a person is stung.

Fire ants, like other ants, may be nesting near buildings and can enter and move through a structure through innumerable tiny cracks and openings. Caulking and otherwise sealing cracks and crevices being used by fire ants can often have great effect in suppressing the population inside. Many effective, easy-to-use silicon sealers and expandable caulk products have been recently developed, including some designed specifically for pest management.

Biological Control. A number of biological enemies of the fire ants have been evaluated as biocontrol agents, including nematodes, bacteria, fungi, viruses, protozoans, and phorid flies. Some show promise, but biological control is not yet a proven effective control tactic for fire ants. Preservation of native ant species may be the best defense against the exotic fire ants.

So far, the most effective of these is a nematode, *Neoaplectana carpocapsae*. In trials, one application has inactivated about 80 percent of treated mounds in 90 days. The straw itch mite, *Pyemotes tritici*, has also been shown to inactivate fire ant mounds. Three to 10 applications at about 2-week intervals gave 70-percent control. Practical use of this mite for fire ant control must await the development of more efficient methods of mass production and increased effectiveness. Another problem is that this mite is a pest of people and animals; it bites and causes dermatitis.

Chemical Control. Many different types of chemical products are available for fire ant control. There are three major ways to manage fire ants with chemicals: (1) treating individual mounds, (2) broadcast treatment of a large area, and (3) spot treatment in and around structures. Remember to consult with your IPM coordinator for specific pesticide recommendations for your area.

Individual mound treatment is generally the most effective method of control. It takes from a few hours to a few weeks to "kill" the mound, depending on the product used. Individual mound treatment is usually most effective in the spring. The key is to locate and treat all the mounds in the area to be protected, not always a simple task. If many young mounds are missed, reinfestation of the area can take place in less than a year. The following discussions describe different ways to treat individual mounds.

For mound drenches, follow directions for dilution of the insecticide and gently wet the mound and surrounding area with insecticide. Then, break open the top of the mound and pour the insecticide dilution directly into the galleries. Mound drenches are most effective after rains when the ground is wet and the ants have

moved up into the drier soil in the mound. During excessively dry weather, effectiveness of the treatment may be enhanced if you soak the soil around the mound with plain water before you treat. A few granular insecticides are labeled for application to fire ant mounds. After application, the granules are watered into the mound.

A growing number of insecticide products are designed to be injected directly into fire ant mounds. They may be injected using a "termite rig" with a soil injector tip, a standard 3.7- to 11-L (1- to 3-gal) compressed air sprayer with a fire ant injector tip, or a special aerosol soil injector system. The mound is injected in a circular pattern, usually at 3 to 10 points. A new product combines insecticide treatment with high-temperature vapors to increase penetration in the mound.

A few bait products are available that may be used for individual mound treatments. The baits take from several days to several weeks to eliminate a fire ant colony, but they can be very effective and are simple to use. Baits are available with a toxicant, a sterilant/toxicant, or a growth regulator. The baits are sprinkled around and sometimes on the mounds. During hot weather, it is best to apply the bait late in the afternoon or early in the evening when the ants begin to forage. Baits must be kept dry.

A few insecticide dusts are labeled for dusting individual fire ant mounds. The dusts are evenly distributed over the top of the mound. Dusts must be dry in order to be effective.

Large fire ant mounds can be eliminated through fumigation. Check with your IPM coordinator to see if these products are registered for use in your area. Only those who have been specifically trained in the use of fumigants should conduct such fumigations.

Several different types of products are labeled for application over wide areas to control fire ants. Granular insecticides are often applied with hand-operated fertilizer spreaders or agricultural application equipment. Sprays are also sometimes used. Because of the broad spectrum of such treatments and their effects on nontarget species, broadcast application of standard insecticides is not a good choice for public land. A better choice is broadcast treatment with insect growth regulator bait, which poses much less risk to nontarget species. For example, fenoxycarb bait has been shown to be very effective for suppression of fire ant populations when applied in one application over a wide area.

If fire ants are nesting in a structure (in a wall void, for example), the nest should be treated directly, usually by drilling and injecting with a residual insecticide. Treatment of ant trails or barrier treatment to keep fire ants from foraging in occupied areas are generally not acceptable choices for Reclamation facilities.

5.4.1.2 Yellowjackets and other social wasps

Only a few of the very large number of wasp species live a social life; these species are referred to as social wasps. Social wasps are predators for most or all of the year and provide a great benefit by killing large numbers of plant-feeding insects and nuisance flies. They become a problem only when they threaten to sting humans. One of the most troublesome of the social wasps is the yellowjacket. Yellowjackets tend to defend their nests vigorously when disturbed. Defensive behavior increases as the season progresses, and colony populations become larger while insect prey becomes scarce. The behavior of foraging yellowjackets switches from that of predator to that of scavenger, and these wasps start to show up at picnics, barbecues, around garbage cans, at dishes of dog or cat food placed outside, and where ripe or overripe fruit is accessible. The number of scavenger wasps can be quite large at certain times and places.

Figure 5.4.1.2.—The yellowjacket has a yellow and black striped abdomen. (U.S. Department of Defense, Armed Forces Pest Management Board)

Ecology. In Western States, there are two distinct types of social wasps: yellowjackets and paper wasps. Yellowjackets are the most troublesome group. Paper wasps are much less aggressive and rarely attack humans. They tend to shy away from human activity, except when their nests are located near doors, windows, or other high traffic areas.

5.4.1.2.1 Yellowjackets (*Vespidae* spp.)

The term “yellowjacket” refers to several different species of wasps in the family *Vespidae*. Included in this group of ground-nesting species are the western yellowjacket, *Vespula pensylvanica*, which is the most commonly encountered species and is sometimes called the "meat bee," and seven other species of *Vespula*. *Vespula vulgaris* is common in rotted tree stumps at higher elevations, and *Vespula germanica* (the German yellowjacket) is becoming more common in many urban areas, where it frequently nests in houses. These wasps tend to be

medium sized, usually black with jagged bands of bright yellow on the abdomen, and have a very short, narrow waist (the area where the thorax attaches to the abdomen).

Nests are built in protected areas like rodent holes and voids in walls and ceilings of houses. Colonies, which are begun each spring by a single reproductive female, can reach populations of between 15 and 15,000 individuals, depending on species. The wasps build a nest of paper made from fibers scraped from wood. It is built of multiple tiers of vertical cells, similar to nests of paper wasps, but with a paper envelope around the outside that usually contains a single entrance hole. If the rodent hole is not spacious enough, yellowjackets will increase the size by moistening the soil and digging. Similar behavior inside a house sometimes leads to a wet patch that develops into a hole in a wall or ceiling.

Immature yellowjackets are white, grub-like larvae or white pupae that develop adult coloring at the time that they emerge as adults. Immatures are not normally seen unless the nest is torn open or a sudden loss of adult caretakers leads to an exodus of starving larvae.

Aerial nesting yellowjackets, *Vespula arenaria* and *Vespula maculata*, build paper nests that are in the open, protected from above by an eave of a building or a limb of a tree. They become extremely defensive when their nests are disturbed. Defending *V. arenaria* sometimes bite and/or sting simultaneously. Wasp stingers have no barbs and can be used repeatedly, especially when the wasp gets inside clothing. As with any stinging incident, it is best to leave the area of the nest site as quickly as possible if wasps start stinging.

5.4.1.2.2 Paper wasps (*Polistes* spp.)

Paper wasps such as *Polistes fuscatus aurifer* and *Polistes apachus* are long (2.5 cm, 1 inch), slender wasps with long legs and a distinct, slender waist. Background colors vary, but most western species tend to be golden brown, or darker, with large patches of yellow or red. Paper nests can be found under eaves, in attics, or under tree branches or vines. Each nest hangs like an open umbrella from a pedicel (stalk) and has open cells that can be seen from beneath the nest. White, legless, grub- like larvae sometimes can be seen from below. Paper wasp nests rarely exceed the size of an outstretched hand and populations vary between 15 to 200 individuals. Most species are relatively unaggressive, but they can be a problem when they nest over doorways or in other areas of human activity, such as fruit trees.

Figure 5.4.1.2.2.—Paper wasps form nests under eaves, tree branches, or in attics. (Gary D. Alpert, Harvard University, U.S. Department of Defense, Armed Forces Pest Management Board).

5.4.1.2.3 Mud daubers (*Sphecidae* spp.)

Mud daubers are black and yellow thread-waisted wasps that build a hard mud nest, usually on ceilings and walls, attended by a single female wasp. They belong to the family *Sphecidae* and are not considered social wasps but may be confused with them. They do not defend their nests and rarely sting. During winter, you can safely remove the nests without spraying.

Injury or Damage. Concern about yellowjackets is based on their persistent, pugnacious behavior around food sources and their fervent colony defense. Usually, stinging behavior is encountered at nesting sites, but scavenging yellowjackets sometimes will sting if someone tries to swat them away from a potential food source. When scavenging at picnics or other outdoor meals, wasps will crawl into soda cans and cause stings on the lips, or inside the mouth or throat if accidentally ingested. Responses to wasp stings vary from only short-term intense sensations to substantial swelling and tenderness, some itching, or life-threatening allergic responses. All these reactions are discussed in detail in the University of California Department of Agriculture and Natural Resources Publication 7449, Pest Notes: Bee and Wasp Stings. Multiple-sting encounters may cause a serious condition that is induced by destructive enzymes in wasp venoms. Red blood cells and other tissues in the body become partially digested and tissue debris is carried to the kidneys, to be eliminated from the body. Too much debris can cause blockages in the kidneys, resulting in renal insufficiency or renal failure. Patients in this condition require medical intervention, even dialysis.

5.4.1.2.4 Control

Mechanical Control. Early in the season, knocking down newly started paper wasp nests will cause the founding female to go elsewhere to start again or to join a neighboring nest as a worker. Also, early season baiting (see "Wasp Baiting" section below) may eliminate some foundress yellowjackets, if prey is in short supply and they are attracted to the bait. Wasp nests are difficult to find when they are first being built because of the limited activity associated with them. Nests are much more noticeable later after populations grow.

Wasp trapping is only effective toward the end of the season when prey is scarce and wasps convert to scavenging. At that time, meat- and fish-based attractants (e.g., cat food) can attract hundreds or thousands of yellowjackets into traps or cages from which they can't escape. Traps and attractants can be purchased at hardware stores or nurseries. However, despite the large number of wasps caught, trapping usually does not reduce populations of scavenging wasps to acceptable levels.

Cultural Control. Social wasps provide an extremely beneficial service by eliminating large numbers of other harmful insects through predation and should be protected and encouraged to nest in areas of little human or animal activity. Although many animals prey on social wasps (including birds, reptiles, amphibians, skunks, bears, raccoons, spiders, preying mantids, and bald-faced hornets), none provide satisfactory biological control in home situations.

Avoidance of wasps and their nesting places is the best way to prevent unpleasant encounters. Wasps can become very defensive when their nest is disturbed. Be on the lookout for nests when outdoors. Insects that are demonstrating directed flight (a beeline in and out of a single location) usually are flying to and from their nest. Scavenging wasps will not become a problem if there is no food around to attract them. When nuisance wasps are present in the outdoor environment, keep foods and drinks covered or inside and keep garbage in tightly sealed garbage cans. Once food is discovered by wasps, they will continue to hunt around that location long after the source has been removed.

If wasps must be eliminated, it is easiest and safest to call for professional help. Do-it-yourself options include early season removal of nests, putting out a poison bait that will be picked up by foraging wasps and taken back to the nest to poison its inhabitants, spraying the nest or nesting site with an insecticide labeled for that use, or trapping wasps in a baited trap designed for that purpose.

Chemical Control. Wasp baiting often provides acceptable control of scavenging yellowjackets in the latter part of the season. Use fish-based canned cat food, cooked hamburger or salmon, or processed meats to formulate poison bait for yellowjackets. The insecticide labeled for this use is micro-encapsulated diazinon, manufactured as Knox-Out 2FM. This material is not routinely found on store shelves, but you may be able to get a store to special order it or get it from a

pest control company. Just a half teaspoon of insecticide is blended thoroughly into 6 teaspoons of the meat product to attract wasps. Place small portions of the mixture outdoors in specially designed bait dispensers and replace with fresh bait every other day (or every day if temperatures are over 32 °C (90 °F) as long as the bait is being consumed. In the micro-encapsulated formulation, diazinon is not repellent to wasps. The bait is taken back to the nest and shared with other adults and larvae. In a week or so, colonies within flight range of the bait stations should no longer pose a problem. Diazinon is toxic to animals other than insects, so follow the label exactly to prevent damaging or killing mammals. Only put the bait out in specially designed dispensers so that animals other than wasps are not able to get at it.

Aerosol formulations of insecticides on the market labeled for use on wasps and hornets can be effective against both yellowjackets and paper wasps, but they must be used with extreme caution. Wasps will attack applicators when sensing a poison applied to their nests, and even the freeze-type products are not guaranteed to stop all wasps that emerge from the nest. It is prudent to wear protective clothing that covers the whole body, including a veil over the face and gloves. In addition, you need to wear protective eyewear and other clothing to protect yourself from pesticide hazards. Wasps are most likely to be in the nest at night. But even after dark and using formulations that shoot an insecticide stream up to 6 m (20 ft), stinging incidents are likely. Underground nests can be quite a distance from the visible entrance, and the spray may not get back far enough to hit the wasps. Partially intoxicated, agitated wasps are likely to be encountered at some distance from the nest entrance, even on the day following an insecticidal treatment.

5.4.1.3 Africanized honey bee (Apis mellifera scutellata)

Africanized honey bees (AHB) are the result of interbreeding between European honey bees and bees from Africa that were released in Brazil in the 1950s. In popular culture, these AHB are known as “killer bees” because of the increased chances of people being stung by these bees. A suspected AHB colony should be reported immediately to the local agricultural extension agent, or the local health department.

Identification. AHB and European honey bees look the same and are about 1.9 cm (3/4 in) long, brownish, with a slight velvety appearance. Discriminating between the two subspecies of honey bees can be done through morphometrics, electrophoresis, and deoxyribonucleic acid (DNA) analysis.

Figure 5.4.1.3.—Honeybees (not Africanized) swarm on F-16 aircraft at Luke Air Force Base, Arizona. (MSgt Todd E. Enderle, 309 AMU/MXACW, 13 Oct 2005, submitted by Wayne Fordham, HQ AFCESA/CESM, Tyndall Air Force Base, Florida, U.S. Department of Defense, Armed Forces Pest Management Board).

Ecology. Four distinct stages make up the life cycle of the honey bee: egg, larva, pupa, and adult. Bees also develop into three different castes: workers, queens, and drones. When honey bees emerge as adults, they continue to develop, with the cuticle hardening in about 12 to 24 hours. Queens begin to lay eggs about 3 days after mating. Hives typically contain a single queen, 100 to 300 drones, and about 40,000 workers. Worker bees forage for nectar, pollen, and water, which are brought back to the colony for use.

Swarming is a natural means of honey bee dispersion with the old queen and about half the bees from the old colony taking flight. Swarms are maintained as a cohesive unit, while scouts seek out a suitable site for the new colony. Absconding is, at least visually, a similar behavior, where the entire hive leaves the nest and relocates. This is usually in response to a severe disturbance like predation or starvation.

Impacts. Although the AHB does not attack unprovoked, it is very defensive of its colony. Stinging is a defensive behavior, and most defensive behavior is in the immediate vicinity of the hive. Away from the hive (except in the case of absconding bees), bees will not sting unless severely provoked. Swarming bees are rarely defensive; however, absconding bees are usually very defensive and are frequently the cause of stinging incidences. Once disturbed, AHB will pursue an enemy 0.40 km (0.25 mi) or more. Bees tend to target objects that resemble natural predators that are typically dark in color, leathery, or furry. Wearing light colored clothes may decrease the chances of being perceived as a predator by AHB. These bees can be life threatening, especially to people allergic to stings, or those with limited capacity to escape. If attacked, people should go quickly to a

safe area (perhaps inside a vehicle) and remove stingers (stingers pump out venom for a minute, even if not attached to the bee). Medical attention should be sought if breathing is troubled, if stung numerous times, or if allergic to bee stings.

5.4.1.3.1 Control

While honey bees play an important role in agriculture, they become a threat to public health when they colonize areas frequented by humans. Bee-proofing buildings may be done by sealing openings in walls and around vents. Fine screen may be installed over various openings to prevent access by bees. Removal of swarms or nesting sites should be handled by a professional with proper training and equipment.

5.4.1.4 Ticks (Ixodidae and Aragosidae)

Ticks are species that can vector a disease, are capable of transmitting a pathogen to humans, or may in some other way affect human health. Therefore, the local or State public health agency should be consulted for more information. The U.S. Department of Defense has developed a technical guide on tick biology, human health issue, monitoring, and control measures.

Figure 5.4.1.4.—Examples of four tick genera, including *Dermacentor* (top row, first three from left to right), *Ornithodoros* (top row, far right), Ixodes (bottom row, first two from left to right), and *Amblyomma* (bottom row, last two from left to right). (Used with permission from the Journal of Dermatology.)

All of the tick species described here are attracted to carbon dioxide and generally prefer low light intensity, high relative humidity, and protection from constant breezes.

Identification. The major tick species are the Lone Star tick, *Amblyomma americanum*, American dog tick, *Dermacentor variabilis*, Rocky Mountain wood tick, *Dermacentor andersoni*, deer tick, *Ixodes scapularis*, and *Ornithodoros* spp.

The identification of medically important species of ticks can be done by local diagnostic facilities at universities or State agencies or with the aid of publications such as Keirans and Litwak (1989), Sonenshine (1979), and the U.S. Department of Health, Education and Welfare (1967), which provide keys and descriptions. There may also be online sources that can be used for tick identification such as the one maintained by the University of Nebraska.

Ecology. For each species of tick, the geographic distribution, habitat, hosts, life cycle, seasonal abundance, responses to environmental factors, and direct and indirect medical effects are described below. Temperature and humidity are the two most important environmental factors affecting tick survival.

Impacts. Ticks are considered harmful because they transmit diseases. Ticks are external parasites on mammals, birds, reptiles, and amphibians. Both males and females feed on blood. Like many other organisms, however, their role in the food chain serves a positive ecological function. Ticks are an essential food source for many reptiles, birds, and amphibians.

Tick-borne diseases of humans are a major public health concern, with most of the diseases of viral origin. The two most important tick-borne diseases in the United States are Lyme disease and Rocky Mountain spotted fever. The onset of Lyme disease is usually characterized by the development of a large, red rash which may develop a characteristic clear central area ("bulls eye"), 1 to 2 weeks after a tick bite, often in the area around the puncture. Other symptoms include joint pains, flu-like symptoms, and neurological or cardiac problems. The most characteristic symptom of Rocky Mountain spotted fever is a rash on the ankles, wrists, and forehead 1 to 2 weeks after the victim is bitten. The rash spreads to the trunk and is accompanied by fever, chills, and prostration. Both Lyme disease and Rocky Mountain spotted fever are transmitted after the tick feeds for several hours. Prompt removal of attached ticks greatly reduces the chances of infection. Both diseases are usually successfully treated with antibiotics in their initial stages. Therefore, early diagnosis is imperative. For this reason, it is recommended that the date of a tick bite be marked on a calendar. If unexplained disease symptoms occur within 2 to 3 weeks, a physician should be consulted.

Ticks may cause paralysis in humans that is reversible when the ticks are removed. Symptoms include paralysis of the arms and legs, followed by a general paralysis which can be fatal if not reversed. The victim may recover completely within a few hours of the removal of the tick. The paralysis may be caused by a salivary toxin transmitted to humans when a tick feeds. Tick paralysis is frequently associated with the attachment of the tick at the base of the victim's

skull; however, the illness occurs from attachment to other parts of the body as well. The highest incidence of tick paralysis in North America occurs near the border of British Columbia, Canada, and the Northwestern United States.

The best means to prevent the transmission of tick-borne diseases and the development of tick paralysis is the prompt removal of ticks. This requires regular inspection of clothing and exposed skin for attached or unattached ticks. Personal protection methods such as wearing of protective clothing, spraying with acaricides, and use of repellents are advised to minimize contact with ticks. To remove a tick, grasp it crosswise with narrow tweezers (do not rupture the tick) as close to the point of attachment as possible. Retract or pull tick firmly away from the direction of attachment; some back-and-forth wiggling may be necessary. Do not twist or rotate the tick. Do not handle ticks with bare hands because infectious agents may enter through mucous membranes or breaks in the skin.

Removed ticks should be immersed in alcohol to kill them. Disinfect the bite site and wash hands thoroughly with soap and water. Removed ticks should be stored in alcohol to allow for later taxonomic identification.

Any case of such a disease should be reported to medical authorities immediately. Frequent or multiple reports of tick-borne diseases should be reported to a Reclamation safety officer. The representative can recommend actions to control disease outbreaks. Closing affected areas may be advisable during such periods.

5.4.1.4.1 Lone star tick (Amblyomma americanum)

This tick species is distributed throughout central and eastern parts of the United States, as well as parts of Central and South America. The Lone Star tick is found in wooded areas, especially where there is dense underbrush, but it is also found in scrub, meadow margins, hedge rows, cane breaks, and marginal vegetation along rivers and streams. The immatures and adults feed on a wide variety of mammals (including humans) and ground-feeding birds.

Each female produces 3,000 to 8,000 eggs, which are deposited under leaf and soil litter in middle to late spring. Incubation may take 30 days or longer, depending on temperature. The newly hatched six-legged immatures, also known as larvae or seed ticks, feed for 3 to 7 days on a host. After full engorgement, the larvae drop from the host into vegetation and shed their skins 9 to 27 days later.

The eight-legged immatures that emerge are called nymphs. These attach to a second host and feed for up to 38 days; the nymphs then detach and rest for 13 to 46 days before they shed their skins to become adults. Adults attach to a third host, feed for 6 to 24 days, and detach. Oviposition occurs 7 to 16 days after the last blood meal. Larvae may survive for 2 to 9 months, and nymphs and adults for 4 to 15 months each; the life cycle may take up to 2 years to complete. Lone Star tick nymphs can move very quickly and may cover a person's legs or arms in less

than 10 minutes. This is a good behavioral characteristic to note to aid in identification of this tick species. This tick is very aggressive and, in some areas, accounts for the majority of ticks feeding on humans.

Adults and nymphs are active from early spring through midsummer, while larvae are active mainly from late summer to early fall. Low humidities and high daytime temperatures restrict the occurrence and activity of these ticks. Lone Star ticks transmit Tularemia, a bacterium-caused disease of rabbits and squirrels, to humans. Tularemia in humans results in an irregular fever lasting several weeks. Lone Star ticks infected with the agents of Rocky Mountain spotted fever and Lyme disease occur in nature, but the species does not appear to be epidemiologically important in the transmission of these diseases.

5.4.1.4.2 American dog tick (Dermacentor variabilis)

The American dog tick is found throughout the United States except in parts of the Rocky Mountain region. It also occurs in parts of Canada and Mexico. Its habitat includes wooded areas, abandoned fields, medium height grasses and shrubs between wetlands and woods, and sunny or open areas around woods. Larvae and nymphs feed primarily on small mammals (especially rodents), while the adults feed mainly on dogs, but will readily bite humans.

The female lays 4,000 to 6,500 ellipsoidal eggs over a 14- to 32-day period and then dies. The eggs usually hatch in 36 to 57 days. Larvae usually engorge for 3 to 5 days, nymphs for 1 to 3 days, and adult females for 5 to13 days. Unfed larvae can live up to 15 months, nymphs 20 months, and adults 30 months or longer. Mating takes place on the host. Adults are active from mid-April to early September. Nymphs are active from June to early September, and larvae are active from late March through July. High light intensity and low relative humidity stimulate questing behavior. This species is the primary vector of Rocky Mountain spotted fever in the Eastern United States and can also transmit Tularemia and cause tick paralysis.

5.4.1.4.3 Rocky Mountain wood tick (Dermacentor andersoni)

This tick is found from the western counties of Nebraska to South Dakota to the Sierra Nevada Mountains, and from northern Arizona and northern New Mexico in the United States to British Columbia, Alberta, and Saskatchewan in Canada. Their habitat is primarily fields and forested areas. This species is especially prevalent where there is brushy vegetation that encourages the small mammal hosts of immature ticks and sufficient forage to attract the large hosts of the adults. Immatures feed mainly on small mammals such as ground squirrels and chipmunks, and adults on cattle, sheep, deer, humans, and other large mammals.

Females lay about 4,000 eggs in plant debris on the soil or in crevices in construction materials, usually in masses of hundreds at a single location. Unfed

larvae may live for 1 to 4 months, nymphs for 10 months, and adults for more than 12 months. Adults and nymphs can be found from March to mid-summer. Larvae are active throughout the summer and are associated with cool soil temperatures, shallow soil, abundant leaf litter, and high relative humidity. This species is the primary vector of Rocky Mountain spotted fever in the Rocky Mountain States and is also known to transmit Colorado tick fever and Tularemia. It also carries tick paralysis in the United States and Canada.

5.4.1.4.4 Deer tick (Ixodes scapularis)

The deer tick occurs along the Atlantic coast of the United States and throughout the Southern States, including Texas and Oklahoma. It may be expanding its range towards the Western States. Deer ticks prefer heavily forested or dense, brushy areas and edge vegetation, but not open areas. An exception to this occurs in upstate New York, where the species is found on well-maintained lawns in residential areas. Larvae and nymphs feed primarily on small mammals (especially the white-footed mouse, other rodents, and insectivores), and also on birds, dogs, deer, and humans. Nymphs aggressively bite humans. Adults feed primarily on deer, but also attach to large mammals (foxes, raccoons, opossums, dogs) and humans.

Females lay up to 3,000 eggs in soil and litter. Eggs take about 1 month to hatch. Larvae engorge for 2 to 3 days during the summer, detach, overwinter on the ground, and molt the following spring. Nymphs feed for 3 to 4 days, detach, and molt in early fall. Adult females engorge for 7 to 21 days, detach, oviposit the following spring, and die. The life cycle may range from 2 to 4 years and is regulated by host abundance and physiological mechanisms. Larvae are active from July through September, nymphs from May through August, and adults in the fall, winter, and early spring (October-May). These ticks require a moist microclimate for survival. Distribution is associated with high humidity and mild mean winter temperatures. However, it is not restricted by winter temperatures, as areas of tick activity occur in Minnesota and Wisconsin. The requirement for high humidity restricts this tick from spreading to arid areas and high mountains, where desiccation is a limiting factor.

The deer tick is the major vector of Lyme disease in the Northeastern and Midwestern United States. It is incriminated as the vector of human babesiosis in the Northeastern United States.

5.4.1.4.5 Ornithodorus spp.

These soft ticks are the vector of relapsing fever (caused by spirochetes of the genus *Borrelia*), which has created serious health problems at the Grand Canyon. The relapsing-fever tick, *Ornithodorus hermsi*, is sand- colored before feeding, but turns grayish-blue after it feeds. The adult female is about 63 mm (¼ in) long.

These ticks are found in cavities of dead trees, log cabins, and human dwellings, and usually feed on squirrels. People are sometimes infected when rodents are removed from an area, and ticks turn to new hosts.

5.4.1.4.6 Monitoring and thresholds

Periodic surveys of potential or known tick habitats can reveal the presence of low-level tick infestations. This permits the application of management procedures to prevent or retard further population increase. Monitoring techniques that have proven effective are as follows.

Examination of Personnel for Attached Ticks. A volunteer wearing protective clothing walks through each sample site and is then inspected. Ticks attached to or walking on the collector's clothing and skin are collected in 70 percent ethanol for later identification and counting. Careful inspection is necessary to prevent the attachment of unnoticed ticks and possible disease transmission to the collector. Collections can be standardized in relation to time, distance, or area units covered during sampling.

Dragging/Flagging. Dragging is done by pulling a white cloth over relatively open ground or "flagging" low-level vegetation (i.e., moving the cloth in a waving motion over and through vegetation) in densely brushy ground. Ticks that are “looking” for passing hosts cling to the cloth and can be removed for identification and counting. The "drag" consists of a 0.83-m^2 (1-yd^2) piece of white crib bedding or corduroy material hemmed on all edges, weighted at one end, and attached to a wooden pole at the opposite end. A rope attached to the two ends of the pole allows the device to be dragged along the ground.

Alternatively, the pole can be gripped at one end so that the cloth hangs vertically downwards, and the device used to flag vegetation. Dragging or flagging success depends upon the degree of contact between the cloth and ground or vegetation surface. The selection of sampling sites may have significant effects on the success of the sampling effort. Sampling sites should reflect favored tick habitats for best success. Sampling should be done under conditions that favor tick presence and activity (e.g., when vegetation is not wet and when ambient temperature is above 10 °C (500 °F).

Dry-Ice Traps. This is the most efficient method of tick collection. It is non-destructive to host animals, does not require a human as an "attractant," and gives more reproducible results than dragging. However, the traps need to be kept in the field for several hours (preferably overnight) for best results. The basic principle is to use carbon dioxide vaporizing from the dry ice to attract ticks onto a white cloth panel. They are easily visible and can be removed periodically (if the traps are set out for a limited time under periodic monitoring), or onto a platform lined with double-sided sticky tape on which they get trapped (if the traps are set out overnight).

Trapping Small Animal Hosts. Small mammals such as rodents and insectivores can be live-trapped at selected sampling sites, with traps set out in grids or line transects. Trapped animals are anesthetized and searched thoroughly for attached ticks, which are removed using fine forceps. Removed ticks can be stored in 70-percent ethanol pending identification and counting. The animal host is released at the site of capture after recovery from anesthesia. Gloves should be worn throughout all animal and tick handling operations. It may be necessary to wear respirators and Tyvek® suits when trapping and handling small mammals because of the potential transmission of diseases such as Hantavirus. A veterinarian or qualified technician should be consulted on the proper usage of anesthetics administered to trapped animals.

Sampling sites for monitoring ticks should be selected in areas that favor ticks or are likely to receive heavy human visitation. A conscientious monitoring program is the basis of effective IPM. Regular surveys should be done at all sites where ticks have been reported by staff or visitors and at other locations that appear to be favorable tick habitats. Complete and accurate records of sampling sites and methods must be kept, so that the progress of tick populations and the effect of control measures can be gauged. After collecting the ticks, store them in rubbing alcohol or freeze in a plastic container to preserve them.

Thresholds. In recreational areas in Oklahoma an arbitrary tolerance threshold of one tick/dry-ice sample has been recommended. The economic threshold in Lone Star tick management recommends that a count of 0.65 ticks per 1 hour of CO_2 exposure (dry-ice traps) be considered (equivalent to one tick per visitor per day, based on the assumption that most human visitors to recreational areas will not spend more than 1 hour per day in tick habitats). This value may not be applicable to your particular situation and a suitable threshold level can be established by conducting regular CO_2 surveys and plotting tick counts against the numbers of tick bite complaints received. This will permit the selection of a complaint threshold level for each site surveyed. Treatment should be conducted to keep tick populations below the selected threshold; a lower "action" level should be selected to trigger treatment programs. The same technique is applicable to other species of ticks as well.

5.4.1.4.7 Control

Education. Ticks are important disease vectors in many regions of the country. Visitors and employees need to be aware of tick species and diseases present in their area, as well as personal protection measures that should be taken by anyone who will be in tick-infested areas. Agencies should provide interpretive pamphlets to inform their visitors about ways to avoid contacts with ticks.

Biological Control. Several species of ants, including fire ants, are known to feed on ticks. Recently, releases of the parasitic wasp *Hunterellus hookeri* have been made on several small islands on the New England coast. This wasp attacks Ixodes scapularis and has been recovered from some of the release sites.

Cultural Control. Wherever possible, visitor activities should be directed toward areas that provide unfavorable habitat for ticks. Regular inspection should be performed to determine when tick management needs to be initiated. Removal of shrubs, trees, or tall grass can be useful in situations where it is consistent with Reclamation policy regarding use of the area. Dense shrub and tree cover and tall grass provide harborage for both ticks and their animal hosts. Removal of excess brush and shrubbery and clearing the canopy trees so that 50 to 80 percent of a management area is exposed to direct sunlight at any time are recommended control practices for walkways, parks, and landscaped grounds. Grass should be kept below 15 cm (6 in) in height to allow the penetration of sunlight and soil ventilation. Such techniques result in higher soil temperatures, lower humidity, and lower soil moisture, all of which lead to higher tick mortality. In one study, such techniques resulted in 75 to 90 percent control of different tick life stages of the Lone Star tick. Mowing vegetation with a bush-hog rotary mower reduced adult deer tick populations by 70 percent in another study.

Mechanical Control. Controlled burning of habitat may reduce tick numbers and may be feasible in a park if it is consistent with a fire management plan. For example, burning tick- infested areas on Great Island, Massachusetts, reduced deer tick populations by 38 percent 6 months after the burn. However, the long-term implications of burning are unclear. Burning typically improves deer browse in the area; thus increased deer abundance may result in the movement of ticks back into the area.

Research has shown that high deer populations can lead to increased Lone Star and deer tick populations, since there will be more hosts from which a blood meal can be obtained. Managing deer populations by hunting, fencing, or environmental modification should be considered seriously before tick infestations become severe and should be done within State and local guidelines. Efforts at deer management should be done in coordination with State natural resources and wildlife department personnel.

Under unusually high tick population pressure, it may be necessary to treat indoor areas. The major methods of non-chemical indoor tick management include regular inspection, elimination of animal (especially rodent) harborage areas, use of food and waste-handling procedures that minimize animal entry and harborage, and animal-proofing buildings. This includes sealing all holes in foundations and walls, and screening (with heavy gauge metal screen) aboveground windows, vents, and other openings, through which animals may enter. A 46-cm (18-in) perimeter border of gravel may prevent movement of ticks from grass areas into buildings. Cracks and crevices around the base of buildings should be sealed with caulk.

Recommended practices include frequent examination of clothing (preferably by another individual) and the body (after showering), destruction of collected ticks, and wearing protective clothing (e.g., coveralls with trouser cuffs taped to shoes,

high-top shoes, socks pulled over trouser cuffs, long-sleeved shirts or jackets, or mesh jackets). Clothing should be light colored so ticks may be easily seen. Periodic surveys of potential or known habitats can reveal the presence of low-level tick infestations, thus indicating the need for application of management practices to prevent or retard further population increase.

Chemical Control. Several insecticides and acaricides provide effective control of tick populations in small, infested areas. At least two treatments are required for control; one in the spring for adult and nymphal stages and the other in late summer for larval stages. Surveillance is necessary to determine times of application (see Monitoring Section for techniques). Low to moderate infestations can usually be controlled by one spring and one late summer treatment; heavy infestations may need two or more treatments in the spring and again in late summer and early fall.

Aerial dispersal of acaricides requires coordination with local, State, and sometimes federal officials. Chlorpyrifos in a granular formulation has been used successfully in tick control by this method however; extensive bird kills have been associated with granular chlorpyrifos treatments. Around the outside of buildings, tick numbers can be reduced by using residual insecticides such as carbaryl (Sevin®), and chlorpyrifos (Dursban®). Follow label instructions. For tick control on pets, use only baths, sprays, and dips that are recommended by your veterinarian.

Vegetation management by herbicides is another tick control option. It produces the same benefits as mechanical management of vegetation—reduced harborages for animal hosts of ticks, reduced soil humidity, and increased soil temperature—all of which are detrimental to tick survival. Management of vegetation by herbicidal and mechanical methods may not always produce comparable results; and herbicidal treatment of woodlots was not as effective as mechanical vegetation clearing in reducing the population of Lone Star ticks.

Personal protection. Ticks can be prevented from attaching to the skin or clothing using repellents. DEET, M-1960, and permethrin provided 81 percent, 95 percent, and 89 percent protection, respectively, against the Lone Star tick. The application of pressurized sprays of 20 percent DEET to the exterior of surfaces of clothing provided 85 percent protection against nymphal and adult Lone Star ticks and 94 percent protection against adult American dog ticks. Permethrin (0.5 percent) gave 100 percent protection against both species.

However, DEET and M-1960 have a disagreeable odor and can cause skin irritations. The most effective repellent/toxicant against all tick species available at present is Permanone® (0.5 percent permethrin), which must be used as a clothing treatment; Permanone® is not intended to be sprayed directly onto the skin. Permanone® remains effective for at least 1 month on unwashed clothing. All pesticide-treated clothing must be washed separately from other clothing.

Indoor Chemical Treatments. Sites such as crevices, baseboards, trimming, furniture, ceilings, floors/carpets, walls behind pictures, bookshelves, and drapes should be spot- treated as needed. Crack and crevice treatments should be done with residual dusts or silica gel. This is the most effective way to use pesticides in a building. Fumigation does not work well in buildings, because ticks can readily re-enter through doorways or windows.

5.4.1.5 Spiders and scorpions

People often fear spiders and scorpions because of misunderstandings concerning their dangerous nature. In reality there are only a few species of spiders and scorpions that warrant caution. Both spiders and scorpions are a normal and desirable part of the ecosystems in which they occur. They feed on other insects, including species which are pests of plants and nuisance species such as biting flies, as well as other spiders and scorpions. Therefore, spiders and scorpions are generally considered to be beneficial organisms. Despite the generally benign nature of most scorpions and spiders, bites or stings by some species can be life-threatening to small children, the elderly, or people who are hypersensitive.

There are three spider groups of medical importance: the widow spiders (including the black widow, *Latrodectus mactans*, the brown recluse spider, *Loxosceles reclusa* (and other related *Loxosceles* species), and the aggressive house spiders (genus *Tegenaria*). There is only one genus of scorpion found in the United States that is of medical importance (*Centruroides*), commonly known as bark scorpions. Less than 1 percent of stings from *Centruroides* are lethal to adults; however, 25 percent of children younger than 5 years who are stung die if not treated. None of these dangerous species of scorpions and spiders bite or sting humans without provocation. The majority of bites or stings occur because the spider or scorpion has been sat, rolled, or stepped on, or because attempts were made to pick up the spider or scorpion.

This document does not include emergency medical procedures for care of persons bitten or stung by these dangerous species. However, some information is provided on how to determine if medical treatment should be sought. This information is provided only as a guide, if in doubt, always consult medical professionals.

Identification. Spiders and scorpions are both arachnids, a group of animals that also includes mites, ticks, and harvestmen (daddy longlegs) and are closely related to insects. Both spiders and scorpions, like insects, have a hard-external body, but spiders and scorpions have four pairs of legs and two body segments (cephalothorax and abdomen) while insects have three pairs of legs and three body segments (head, thorax and abdomen).

Spiders have a pair of fangs used to inject venom into prey, whereas scorpions lack fangs but instead have a stinger located at the end of a segmented erectile

tail. Scorpions also have a pair of claws or pinchers (modified pedipalps) but do not produce silk. Pinchers are absent in spiders, but they possess spinnerets that produce silk used to weave webs.

Ecology. Scorpions are predators of other invertebrates and small lizards and rodents. Scorpions can alter their metabolism and withstand long periods of starvation (up to 5 months) without any noticeable effect. In areas where there are occasional subfreezing temperatures, scorpions will hide in warmer rock and bark crevices. The upper lethal temperature for scorpions is about 50 °C (122 °F).

Scorpions give birth to live young. Immediately following birth, the young scorpions crawl onto the back of their mother, where they remain for 5 to 15 days. The young scorpions are white and soft during this time. Following pigment development (tanning), the young scorpions will leave their mother's back and begin to forage for food. Scorpions may live for several years, depending on the availability of food and water.

In the United States, scorpions are most abundant in the arid and semi-arid regions of the Southwest. No scorpion species occur in the Rocky Mountains, Northcentral, or Northeastern United States. Only one species occurs throughout most of the Southeastern United States, and one species occurs in northern Florida, while three species occur in southern Florida. Southern Nevada, southeastern California, and central Arizona have the highest diversity of scorpion species in the United States.

The bark scorpion, *C. exilicauda* (=*sculpturatus*), which is the only American species of scorpion whose sting may be life-threatening, occurs primarily in the southeastern part of Arizona, but it may also be found in southern New Mexico and southern California. A related but less venomous species, *C. vittatus*, occurs in Texas and in the Southeastern United States from South Carolina south to Florida and west to New Mexico. (*C. vittatus* was formerly divided into three species: *C. vittatus*, *C. partherienois*, and *C. chisosarius.*)

Typically, scorpions are nocturnal and are hiding or undercover during daylight hours. Much of this behavior is to decrease moisture losses. Scorpions need this moisture and, for this reason, may be attracted to water sources. Locations associated with human habitation often have increased water sources in arid regions. These areas attract scorpions and increase the likelihood of human-scorpion encounters.

The bark scorpion is almost always found associated with trees and is almost never found hiding in burrows, except during periods of hibernation. Its climbing habit distinguishes it from all other scorpions in its geographic range.

Scorpions are attracted to water sources in buildings. Bathroom and kitchen areas are the most frequent places scorpions can be found at night in buildings. During the day, scorpions will seek out hiding places such as cracks and crevices in the floor, cabinets, attics, wall voids, and crawl spaces. Scorpions are most often a

problem in buildings in newly developed areas (within 3 years). This is attributable to the disturbance or destruction of the scorpion's territories. Additionally, buildings near arroyos or dry riverbeds may experience an influx of scorpions during periods of rain as the scorpions seek out higher ground. Scorpions in buildings are not likely to meet their normal requirements of temperature and prey density.

5.4.1.5.1 Monitoring and thresholds

Scorpions can be detected in an area by trapping (with pitfall traps) and visual scouting. Visual scouting for scorpions can be done during both daylight and dusk (or early evening) hours. During daylight hours, a visual search under rocks, loose bark, and other debris (while wearing leather gloves) can confirm the presence of scorpions. At night, areas may be searched using an ultraviolet fluorescent light fixture. Scorpions glow brightly under black light and are extremely conspicuous, even from yards away.

5.4.1.5.2 Control methods

Programs to educate the public should be implemented in areas where scorpions are known to occur. These should include identification of scorpions, especially recognition of the dangerous species occurring in the region. People should be encouraged to avoid risky activity in areas where scorpions have been observed. The program should also educate the public about the beneficial role that scorpions play in the ecosystem, and the importance of scorpions as natural enemies of other arachnids and insects. Lastly, preventative behaviors should be outlined, and the groups of people most at risk should be identified.

Additional precautionary methods that should be included in the education program are: (1) wearing leather gloves when moving objects and collecting firewood at campsites or in outdoor areas; (2) when camping, invert and shake out clothes, sleeping bags, and other items that have been in contact with the ground or trees, and shake out shoes before putting them on; and (3) always wear shoes when walking at dusk or at night.

The best methods for controlling scorpions are: (1) those that alter the habitat where human contact is likely to make it less suitable for scorpions; and (2) the creation of barriers that restrict the movement of scorpions into buildings and areas where contact is likely. Cultural methods, such as sanitation and elimination of harborages, have been found to be effective in reducing scorpion numbers. Barriers to movement of scorpions into dwellings can also be effective in reducing exposure to scorpions. Barriers for scorpion exclusion include caulking windows and holes around plumbing.

Cultural Control. Sanitation and removal of debris are the primary methods recommended for the control of scorpions. Firewood should be stored away from the sides of buildings, off the ground, and kept dry. Other debris such as loose boards, rock piles, and trash should also be moved away from buildings. Shrubs should be pruned so that they do not make contact with the exterior of buildings.

Elimination of sources of open water may also reduce the occurrence of scorpions. Proper maintenance of toilets and plumbing to reduce leaks and coating the inside lip of toilets with petroleum jelly will reduce access of scorpions to water. Drains should be screened or plugged when not in use to prevent access from the outside. Good runoff of water away from the house should be provided. In order to create barriers to scorpion movement into dwellings, window frames and screens should be periodically checked for holes large enough to allow for scorpions to enter. Screens should be repaired, and window frames should be caulked to fill all gaps. Beds and cots can be protected by placing the legs into clean widemouth jars (scorpions cannot climb clean glass surfaces). Holes associated with wiring and plumbing should also be caulked to fill gaps.

Chemical Control. There is little evidence that chemical control tactics are effective against scorpions, so they should only be considered as a last resort. However, chemical control methods have been used to control scorpions in areas in which infestations are already identified. There are chemicals registered for the control of scorpions, but proper application is essential for adequate control.

Application of insecticides during daylight hours is largely ineffective against scorpions, since scorpions are only active at dusk and at night. Some residual insecticides are registered for use; these may be the method of choice if scorpions are a persistent problem inside buildings (after attempts have been made to exclude them through cultural methods). If scorpions are found in buildings or are frequently found in outside areas where visitors are likely to be active after dark, the use of pesticides may be necessary. If pesticide use is considered, they should be applied to all potential hiding places and points of entry (including, but not exclusively, wall voids, cracks and crevices, attics, and window sills). Dusts are preferred because they can be blown into wall voids, etc.

First Aid. Consult a current first aid manual for the best information on treating spider bites. Generally, however, ice may be applied for a short time to reduce the pain at the site of the bite or sting. If in doubt about the seriousness of a bite or sting, or if a person is bitten or stung by any of the medically important species discussed in this section, contact your local poison control center or a physician immediately. Also, collect the scorpion or spider in question, if possible, to assist in the treatment.

The sting of most scorpion species, and the bite of most spider species, are not considered dangerous. However, if a person is stung by a scorpion in an area in which the bark scorpion occurs, medical attention should always be sought because its sting may be life-threatening. Additionally, any bite or sting may

elicit an unusual allergic reaction by persons who are hypersensitive to the bite of a specific species. For this reason, all bites must be examined to ensure the safety of those involved. A hyperallergic reaction can lead to anaphylactic shock, and in very severe cases, respiratory distress may develop. It is not unusual for a person to have some pain and numbness in the same region as the site of the bite. However, if, for instance, a person is bitten on their hand and their legs begin to swell, this is indicative of a systemic reaction, and this person should receive medical attention as soon as possible. People who are known to be hypersensitive to other stinging insects, such as bees and wasps, are not necessarily hypersensitive to spider bites or scorpion stings. Likewise, each spider or scorpion has a very specific type of venom, and a person may be sensitive to the venom of one species and not sensitive to the venom of a closely related species. Lastly, some antivenoms are available for treatment of some bites and stings, but their availability is variable. Contact your local poison control center for information regarding antivenoms if dangerous spiders or scorpions are a problem in your region.

5.4.1.5.3 Brown recluse (Loxosceles reclusa)

Identification. The brown recluse spider, *Loxosceles reclusa*, and related species, which are found in the Desert Southwest, are referred to as violin or fiddleback spiders because they have a dark fiddle shaped pattern on the front half of their upper body (the cephalothorax). Focusing on the violin pattern often leads to misidentifications because it is often hard to see. They vary in color from tan to dark brown. The best (but still difficult) way to identify the brown recluse is to look at the eye pattern. The brown recluse has six eyes arranged in pairs with one pair in front and a pair on either side. Most spiders have eight eyes in two rows of four. Brown recluses are only found in the Midwestern United States. Other recluse species are found in the Southwestern United States. It is highly likely that reports of this spider in other areas are the result of improper identification.

Figure 5.4.1.5.3.—Brown recluse spider. (Mr. Norman Feller, U.S. Department of Defense, Armed Forces Pest Management Board).

Ecology. The brown recluse spider is sedentary and builds an irregular web that is hidden behind objects. Females lay eggs in flattened egg sacs that are frequently attached to the underside of objects. Mating in this species occurs from February to September. Up to 40 spiderlings may hatch from a single egg sac. A single female may produce up to five egg sacs in a summer. Females can live up to 4 years, males less.

Indoors, the brown recluse can usually be found in infrequently disturbed areas away from light sources, such as behind pictures, beneath or behind furniture, in boxes, in clothing, among stored papers, between the corrugation of boxes, and under food sacks. In other words, they are reclusive. The natural habitat of the brown recluse includes the underside of rocks, loose bark, and crevices in decaying logs. However, many outdoor refugia provided by the activities of man are frequently inhabited by the brown recluse spider. For example, a survey of piles of junk in Kansas, piles of old tires and inner tubes, furniture, old boards, and trash were found to be inhabited by the brown recluse. Once the debris was removed and the natural vegetation returned to the area, the colony was eliminated. The brown recluse spider occurs in the middle of the United States, with other similar species along the southern part of the Western United States.

5.4.1.5.4 Widow spiders (*Latrodectus spp.*)

There are five species of widow spiders (*Latrodectus*) in the United States. The combined geographic range of these spiders encompasses the entire United States. Three of these species can generally be considered to be "black widows".

Identification. Females of all of these species are metallic black with reddish marks commonly forming an hourglass shape on the underside of their thorax. The most well-known species, the common black widow spider, *Latrodectus mactans*, occurs from southern New England to the Southern United States. The Northern widow, *L. variolus*, occurs from the Mid-Atlantic States north to Canada. The western widow, *L. hesperus*, occurs west of the Rocky Mountains. Two additional species, the brown widow, *L. geometricus*, and the red widow, *L. bishopi*, are tropical species whose United States distribution is restricted to southern Florida. *Latrodectus geometricus* is another introduced species that primarily occurs in domestic situations, but its distribution is sporadic.

Figure 5.4.1.5.4.—Young female specimen of the southern black widow, *Latrodectus mactans* (Fabricius). Picture taken in Dryburg, Halifax County, Virginia. (Photo credit:: Robert Keith Snead, U.S. Department of Defense, Armed Forces Pest Management Board, November 2007).

Widow spiders are cobweb builders; a typical web of a widow spider is a small, tangled maze of coarse fibers that are made in dark corners or crevices. Frequently, these webs are made near ground level. These webs may not even be recognizable as an active spider web. Eggs of the widow spiders are laid in sacs of silk within the female's web. A single egg sac may contain up to 400 eggs. The eggs of widow spiders hatch in 3 to 4 weeks. The hatchlings are highly cannibalistic; therefore, most of the young will be consumed by their brothers and sisters. Web-spinning spiders, such as the widow spiders, are not active outside of their webs. This is especially true of the western widow spider, which creates webs primarily in cracks and crevices.

5.4.1.5.5 Aggressive house spiders (*Tegenaria*)

The aggressive house spiders are in the genus *Tegenaria*. Only one species, *Tegenaria chiricahuae*, is native to the United States, but at least six introduced species of *Tegenaria* now occur in the United States. These spiders, as a group, are often referred to as funnel-web spiders. They build funnel shaped webs in dark, moist areas such as basements and crawl spaces, and then sit in these webs and wait for prey to walk by.

Identification. Generally, these spiders are yellow to pale tan in color with long legs. These spiders occur in highest frequency in July through September and reproduce during this period. Females produce an egg sac that is placed near the opening of the funnel in their webs. Eggs hatch the following spring.

Although the bite of these species is not considered to be as dangerous as that of either the brown recluse or widow spiders, it can cause a similar ulceration of the skin as the brown recluse and may involve systemic reactions. The species that

cause the worst bite reactions are found in the Northwestern United States; *Tegenaria agrestis* occurs from Idaho to Vancouver and Winnipeg in Canada. It builds a web at or near ground level, and it rarely climbs vertically. This spider will bite when cornered or threatened. This may be related to their hunting strategy and may increase the likelihood that humans will be bitten by these spiders.

5.5 Vertebrate pests

5.5.1 Snakes

Many people understand little about snakes and are susceptible to widely believed misconceptions. This has created a generalized fear of all snakes with the assumption that they are all dangerous.

Snakes are ectothermic (they rely on external sources to control their body temperature and, like most reptiles, lay eggs. Rattlesnakes are an exception, giving birth in autumn to 5 to 12 live young, each 0.3 to 0.6 m (1 to 2 ft) long. Snake scales are smooth and dry and the skin is often shed more than once each year to accommodate their growing bodies.

Since snakes are ectothermic, they must avoid extremes in temperatures and hunt preferably during mild conditions. Their forked tongues and heat-sensitive facial pits are used to determine what exists in their environment and to acquire prey. It is important to remember that a dead rattlesnake, even if it has been decapitated, is still capable of biting (not striking) and injecting poison. The snake's heat sensory pits are active until rigor mortis sets in and will trigger a biting response if a warm object, such as a hand, is placed near the snake's mouth. Most snakes prey predominantly on rodents, although some also eat bird eggs, nestlings, and insects.

Snakes need cool, damp shelters and may take residence under and possibly inside buildings. This behavior may become more noticeable in the fall, when snakes seek areas to hibernate for the winter. Nonpoisonous snakes do not pose any major problems for humans besides fear and sometimes being pests. Poisonous snakes, however, may cause a health hazard by biting people, pets, and livestock.

Only a minority of snakes inhabiting the 17 Western States are poisonous, and these include rattlesnakes (*Crotalus* spp.), the massasauga (*Sistrurus catenatus*, a small rattle snake), the copperhead (*Agkistrodon contortrix*), cottonmouth water moccasin (*Agkistrodon piscivorous*), and the western coral snake (*Micruroides euryxanthus*). All of these, with the exception of the coral snake, are pit vipers.

Identification. There are six basic ways to distinguish the pit vipers from their nonpoisonous neighbors:

- Facial pits between the nostrils and eyes.
- Vertical and elliptical pupils that may look like thin lines in bright light (nonpoisonous snakes have round pupils).
- Single, nondivided belly scales from the head to the tip of the tail (nonpoisonous snakes have two rows of scales).
- Broad triangular head distinctly broader than the neck.
- Short, stubby tail instead of long and whip-like (only rattlesnakes have rattles).

The coral snake is not a pit viper but the coloration is fairly distinctive. This snake is ringed with red and black, separated by narrower rings of yellow or white. The nonpoisonous king snake is similar in pattern but red bands are bordered by black. Thus, the old saying, “Red to yellow kill a fellow; red to black venom lack.”

5.5.1.1 Control methods

Prevention. Snakes may seek shelter in basements, sheds, or crawl spaces in cold weather. There are several ways to make premises unattractive to snakes and to exclude them from houses:

- Eliminate cool, damp areas where snakes hide; remove brush and rock piles; keep shrubbery away from foundations; and cut high grass.
- Control insect and rodent populations (the snakes' primary food source) to force them to seek areas with a larger food supply. Put grains in tightly sealed containers, clean up residual pet food, cut grass short, and clean up debris.
- In snake-infested areas, construct a snake-proof fence around the backyard or play area. Use galvanized hardware cloth with a 0.63-cm (1/4-inch) mesh and a height of 91 cm (36 in) and bury 15 cm (6 inches) deep, slant outward at a 30-degree angle. Make certain the gate fits tightly and swings into the play area. Keep all vegetation away from the fence to prevent snakes from climbing over it.
- To prevent snakes from entering basements and crawl spaces, seal all 0.63-cm (1/4-inch) or larger spaces with mortar, caulking compound, or 0.32 cm (1/8-in) hardware cloth. Check for holes or cracks around doors, windows, water pipes, electrical lines, etc.

Repellents. Commercially available snake repellents are not generally successful in repelling snakes. Several potential home remedies have been evaluated to determine if they would repel black rat snakes (*Lampropeltis getulus*). Treatments included: gourd vines, moth balls, sulfur, cedar oil, a tacky bird repellent, lime, cayenne pepper spray, sisal rope, coal tar and creosote, liquid smoke, artificial skunk scent, and musk from a king snake (they eat other snakes). None of these remedies repelled black rat snakes.

Removal. Several humane methods are available for removing snakes. A good way to remove a nonpoisonous snake is to sweep it into a large bucket with a broom and then release it outdoors.

Damp burlap sacks covered with dry sacks to retain moisture are attractive denning sites when placed along a wall in a basement or crawl space. Check the bags daily and remove with a shovel.

Glue boards or glue trays are effective to remove snakes from buildings. They are made of heavy cardboard or plastic rectangles coated with a tacky substance (similar to fly paper) that traps snakes that move across them. Fasten about 144 in2 of glue boards to a 0.63- by 45.7- by 61-cm (1/4- by 24-by 18-in) piece of plywood and place it along the wall where snakes are likely to cross. For humane reasons, do not leave snakes on glue boards any longer than necessary. To release the snake harmlessly, pour vegetable oil over it to break down the glue. Be sure to place glue boards where pets or other nontarget species will not get caught.

Use drift fence and funnel traps to capture snakes at dens or open areas. Roll a 0.9- by 1.2-m (3- by 4-ft) piece of 0.63-cm (1/4-inch) hardware cloth into a tube about 0.3 m (1 ft) in diameter and 1.2 m (4 ft) long, with one end closed and a funnel leading into the end facing the den having a funnel leading into it. The slope of the funnel makes it difficult for snakes to crawl out. If a box is placed inside the trap, snakes usually will hide in it instead of expending energy to find a way out. If you need to trap in an area away from a den, a drift fence on both sides of the funnel will channel snakes into the trap. The fences should be of 0.63-cm (1/4-inch) mesh and extend vertically for about 0.6 m (2 ft). Because nontarget animals are vulnerable to this trap, use it primarily at den sites.

5.5.1.2 Safety

The best safety measure against poisonous snakes is to be prepared for a possible encounter with them, especially if hiking in their habitat. Be able to recognize the poisonous snakes in the area by studying a field guide of reptiles, visiting a zoo, or by remembering the characteristics of poisonous snakes. In areas inhabited by rattlesnakes, wear long loose pants and calf-high leather boots or, preferably, snake guards. Rattlesnakes generally are nonaggressive toward humans unless they are startled, cornered, or stepped on. Alert them of your approach by sweeping grassy areas with a long stick before entering. Never jump over logs,

turn over rocks, or sit down carelessly. Always look carefully where you place your hands, feet, or body. Remember, rattlesnakes do not always shake their rattles before striking, so do not rely only on your sense of hearing. If you are confronted with a rattlesnake, remain calm and try to back away slowly and carefully. Do not handle poisonous snakes.

5.5.1.2.1 Snake bites

If you are bitten by a poisonous snake, remain as calm as possible as panic may trigger adverse physical reactions. Do not try to kill the snake. It may lead to additional bites and delay your arrival at the hospital for professional treatment. Since there is a single antivenom available for use against all native pit vipers in the United States, there is no need to determine the species of snake. There is separate antivenom available for the easily identified coral snakes. These snakes account for less than 1 percent of the poisonous snakebites in the United States. People intentionally handling coral snakes account for most bites by this snake. Immediately after being bitten, check the injured area. If it is a poisonous snake bite, there may be one or two visible fang marks in addition to teeth marks. The common and fairly quick reactions to envenomation are swelling and pain in the bitten area followed by a black and blue discoloration of the tissue and possibly nausea. Painful swelling of lymph nodes in the groin usually occurs within 1 hour if the bite is on the foot or leg. Mojave rattlesnake bites may present different clinical signs, such as severe neurologic effects. Coral snakes conduct venom with a chewing motion and must hang on to their victim for a period of time to achieve venom introduction.

The most useful snakebite first aid kit consists of car keys and a phone for calling the hospital. If bitten, remain calm and get to a hospital as soon as possible. Call ahead to the hospital so that the emergency room and physician can prepare for arrival of the patient. If possible, have another person drive the victim to the hospital.

Remove anything from the body that may cause restriction (rings, shoes, watches, etc.) before the swelling begins. Although some disagreement exists among physicians, tourniquets, incision and suction, or treatment with ice usually are not recommended for native poisonous snakebites. All of these methods tend to increase tissue damage. Because antivenom may cause severe allergic reactions, it is recommended that antivenom be administered in a hospital and its effects closely monitored. Check with a local medical professional for current treatment methods and, if desirable, get more than one opinion. Be familiar with the suggested emergency procedures before the incident occurs. By being prepared, you may react to the situation more calmly, effectively, and safely.

5.5.1.3 Legal status

It is legal to kill rattlesnakes only during an open season or when necessary to protect life or property, provided that the method used is in accordance with city or county ordinances. The most common methods used to kill rattlesnakes are clubbing or shooting. Some rattlesnakes and all nonpoisonous snakes are classified as nongame wildlife and are protected by State law, except as noted above. There are currently no frightening devices or legal toxicants or fumigants available to control snakes.

Venom from poisonous snakes is used in medical research and has been beneficial to people in unexpected ways. One recent example is a successful and widely-used high blood pressure medicine that was developed using the chemical pattern of snake venom as a guide. Other research involves testing snake poisons for use in treating blood and heart problems and for controlling harmful bacteria. Also, snakes kill and eat rats, mice, insects, gophers, and other animals that often are considered pests. Snakes can capture these in burrows or under cover where other predators cannot reach them.
Snakes probably won't eliminate pests, but they do help keep numbers in check. King snakes and milk snakes commonly eat other snakes, including poisonous ones. Overall, snakes are an important part of our natural world and should be left alone.

Prevention is the key to effective snake control. Modification of property to make it undesirable for snakes and making preparations for possible encounters are important. Learn the distinguishing characteristics between poisonous and nonpoisonous snakes and what poisonous species reside in your location. Do not kill snakes indiscriminately or because of fear.

5.5.2 Birds

5.5.2.1 Legal status and permit process

All birds are protected by State and/or Federal law except pigeons (*Columbidae* spp.), European starlings (*Sturnus vulgaris*), and house sparrows (*Passer domesticus*). It is illegal to kill any other bird species without a special permit; it is also illegal to indirectly cause the death of a protected species. For example, if you put out a toxic chemical to kill starlings, and a protected bird is killed in the process, you are legally responsible.

Furthermore, it is illegal to disturb a bird that has young or eggs in the nest. A permit is required if protected birds are to be harmed by damage control techniques. A "Migratory Bird Depredation Permit" can be obtained from the U.S. Fish and Wildlife Service (FWS). Obtain a permit application from your State office of the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA-APHIS.

5.5.2.2 Control methods

There is no one best way to control birds around facilities. There are, however, a variety of humane and effective bird control products that include the use of barriers, repellents, and visual deterrents. Other more aggressive actions include egg destruction, trapping of adult birds, and lethal methods of bird control.

Exclude Birds. Factors to be considered in determining the most appropriate methods are effectiveness, longevity, maintenance, ease of application, cost, and aesthetics. Materials include tactile repellents, pins and wires, netting, and permanent materials such as screening or hardware cloth.

One of the best approaches is to use nylon netting. The material is very easy to use, durable, and can often be integrated into the architecture of the structure. Pins and wires or nylon line can be used, but they often are more labor intensive to install and, in most applications, are more permanent. The tactile repellents are easy to apply but can disfigure structures if applied incorrectly, tend to dry out or collect debris, and are the least permanent of the techniques.

The best way to reduce problems in buildings is to exclude birds from the buildings. This can be costly at first, but in the long run it is often the most cost-effective method. Initial architectural design should be ensured to be bird free.

Visual Repellents. A number of visual repellants can be used to repel birds: Beach-ball sized, scare-eye balloons come in a variety of colors and are variable in success in repelling birds. The balloons must be free to move in the wind to be effective.

Hang plastic strips in doorways. Block doorways that cannot be kept closed by hanging strips of heavy plastic vertically in the doorway. They allow machinery and people to pass through but keep birds out.

Close all openings more than 1.27 cm (1/2 in) wide. Block openings to lofts, vents, and eaves with wood, metal, glass, or wire mesh. Repair broken window panes.

Use hawk and owl imitations. Many of these materials are only effective for short periods of time. There have been reports of birds nesting directly on these products.

Habitat Modification. Reduce the attractiveness of the roosting and nesting sites if exclusion is not possible or economically feasible. Pruning trees to eliminate dense foliage may limit use by some birds.

Change the angle of the roosting ledge to at least 45 degrees. Fit roost sites with slanted metal or wooden boards at an angle of at least 45 degrees.

Install mechanical perch repellents (porcupine wires). These consist of sharp wires or spikes that extend outward at all angles. The spikes are fastened to a solid base and can be installed wherever birds roost or nest. The points inflict temporary discomfort, causing birds to avoid these surfaces. These materials are not effective against smaller birds, such as house sparrows, because the birds can fit between the points and use the site for nesting.

Install electronic bird-control devices on roost and nest sites. This device consists of a cable embedded with two electrical conductors. The conductors carry an electric charge and give birds a shock when they land on it. These devices must be maintained to be effective.

Chemical perch repellents. These are sticky or slippery substances that you caulk, spray, or paint on rafters and ledges where birds perch or nest. They do not work in very dusty areas. Sticky repellents can be very hazardous. They kill animals by getting into their nose and throat and suffocating them. Or, the goo sticks to feathers or fur, causing the poor creature to chill or overheat to death. The messy stuff also damages buildings and is rendered ineffective by dust and debris—which, cost more money without solving the problem. This is not a recommended control method.

Install catwalks along the rafters and ledges to allow cats access to prime roosting and nesting sites. Birds avoid these areas when cats are patrolling.

Noise-making devices are usually disturbing to humans but have little permanent effect on roosting pigeons. High-frequency (ultrasonic) sound is inaudible to humans but has no effect on pigeons. Revolving lights, waving colored flags, balloons, rubber snakes, owl models, and other devices have little or no effect in the long term.

Reduce Reproductive Rate. Along with other methods, use techniques to reduce bird reproduction rates. Such methods may only be used against species that are not State or Federal protected. These include pigeons, house sparrows, and European starlings.

Use a hook fastened to the end of a long pole to tear down nests at 2-week intervals. If you can reach the nests, take a pin and poke holes in the eggs. This method often works better than outright destruction of nests. The reason is that the birds will continue to sit on the eggs waiting for them to hatch instead of building a new nest, as they often do when eggs are destroyed. Both methods are very time consuming.

Trapping. Birds can be caught and removed with live traps. Many designs for traps are available, or traps can be purchased. The most widely used design is the "bob" trap, so named because of the swinging rods, or bobs, at the entrance. Pigeons can push their way into the trap, but because bobs only push inward, the

birds can't get out. The most effective house sparrow traps are funnel traps. Their large entrances make it easy for birds to enter, but they also make it easy for birds to escape.

Traps should be checked at least daily, and the nontarget birds should be released. Target species may either be killed humanely or released in another location. For the traps to work efficiently, the area must be prebaited for several days. This accustoms the birds to feeding in the area and, if possible, gets them used to feeding in the traps. After a few days of prebaiting, the traps should be set and checked frequently. The effectiveness of some traps is improved when decoy birds are kept inside. This gives incoming birds a feeling of security. Always keep a supply of food and water in traps.

Lethal Methods. Review the section above on legal status to determine permit requirements for using lethal methods. When using lethal methods, be careful not to harm nontarget species. Lethal techniques may only be used on the three nonprotected species and on blackbirds that cause damage to an area. Consult USDA-APHIS Wildlife Services officials before using lethal control methods if you are unsure whether protected species could be harmed.

Pigeons, starlings, and house sparrows can be removed by shooting in areas where this is legal. Refer to local firearms ordinances or consult your State Game Commission to determine the legality of shooting in your area. Shooting can be effective in removing the few pigeons that persist around facilities following a reduction program.

Chemical frightening agents are sold which cause birds to display distress symptoms, such as erratic flight which frightens away other members of the flock. As these agents are nondiscriminatory, we strongly discourage their use. Depending on the amount of bait consumed, birds will either die or become ill. Only certified pesticide applicators with bird control training may use these compounds.

Lethal methods of control are less effective over the long run. While they temporarily reduce numbers of birds, birds will continue to be attracted to areas that provide food and roosting and nesting habitat. Unless an attractive environment is modified to be less attractive, birds will continue to colonize the area. (Please refer to the University of Nebraska’s Web site at http://www.ianr.unl.edu/pubs/ for more specific information on pigeon repellents and toxicants.)

5.5.3 Mammals

5.5.3.1 Pocket gophers (Geomyidae)

Identification. Pocket gophers are burrowing rodents of the family *Geomyidae*. They have fur-lined cheek pouches or pockets outside of the mouth that they use

for carrying food. They can close their mouth behind their incisors, which they often use for digging. Pocket gophers are powerfully built, especially in the front quarters, and are well suited for an existence in an underground burrow system. Pocket gophers are medium-sized rodents ranging from about 12 to 36 cm (5 to 14 inches) in length and weighing 90 to 500 grams (g) (3 to 20 ounces [oz]). Their fur is very fine and highly variable in color, ranging from nearly black to pale brown to almost white.

There are 5 general and 33 species of pocket gophers in the Western Hemisphere. Three genera and 13 species occur in the United States. The major external features differentiating these genera are the sizes of the forefeet and claws and the front surfaces of their upper incisors: *Thomomys* have smooth-faced incisors, small forefeet, and small claws; *Geomys* have two grooves on each incisor, large forefeet, and large claws; and *Pappogeomys* have a single groove on each incisor, large forefeet, and large claws.

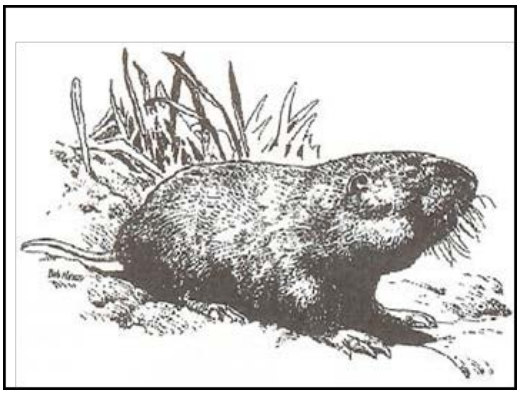

Figure 5.5.3.1.—Pocket gopher.

Ecology. Pocket gophers are found only in the Western Hemisphere, ranging from Colombia in the South to Canada in the North. The 10 species with substantial populations in the United States are variable in their distribution, as follows:

The plains pocket gopher (*Geomys bursarius*) is widely distributed on the Great Plains. The southeastern pocket gopher (*Geomys pinetus*), the Texas pocket gopher (*Geomys personatus*), and the desert pocket gopher (*Geomys arenarius*) have more limited distribution in the Southeast and Southwest. The yellow-faced pocket gopher (*Pappogeomys castanops*) also occurs in the Southwest.

The northern pocket gopher (*Thomomys talpoides*) and the southern pocket gopher (*Thomomys umbrinus*) are widely distributed in the West. The other three species, the Mazama pocket gopher (*Thomomys mazama*), the mountain pocket gopher (*Thomomys monticola*), and the Camas pocket gopher (*Thomomys bulbivorus*), have rather limited distributions.

Fan- or kidney-shaped mounds are characteristic evidence of the presence of pocket gophers. They nearly always keep their burrow system closed with a plug of soil. Open burrows are usually those that are being constructed or that have been opened by the occupant so that it can forage on the surface. Pocket gophers are solitary animals. Usually, there is only one gopher per burrow system, but obviously there are exceptions during the breeding season and when females have young.

Burrow systems usually consist of a main burrow 10 to 50 cm (4 to 20 inches) below the ground surface (this varies with species, soil type, and climate) and a variable number of lateral burrows off the main. There are deeper branches off the main burrow that are used as nests and food caches. Burrow diameter varies with the body size of the species but usually is 5 to 12 cm (2 to 5 inches). Pocket gophers also tunnel through snow above ground. Soil from below ground is pushed into the snow tunnels; when the snow melts, the casts (tubes) remain on the ground until they weather away. Mound building by pocket gophers increases in spring, decreases in summer, and increases again in fall.

In the Northern United States, pocket gophers have one litter per year. In the Southern States, some species may have two litters, or at least a prolonged breeding season. Litter sizes range from 1 to 10 but usually average 3 to 5. Average lifespan of pocket gophers may be related to density. *Thomomys* live for an average of 1 to 3 years. *Geomys* may average over 2 years and have reached 7 years in the wild.

Densities reported for the different pocket gopher species are highly variable. For *Thomomys*, densities of 40 to 50 per ha (15 to 20 per acre) are common and densities as high as 150 per ha (62 per acre) have been reported. For *Geomys*, densities are lower; 20 per ha (6 to 8 per acre) is about the highest reported.

Numerous predators eat pocket gophers. Some, such as weasels and snakes, pursue them in their burrows. When pocket gophers are on the surface, they are taken by a variety of birds of prey and mammalian predators. Badgers are one of the principal predators of pocket gophers and are adept at digging them out. Such digging can be very destructive to hydraulic structures.

Pocket gophers occupy a wide variety of habitats from low coastal areas to elevations above 3,600 m (12,000 ft). They are found in a wide variety of soil types and conditions. They reach their greatest densities on friable, light-textured soils with good vegetation, especially when the vegetation has large, fleshy roots, bulbs, tubers, or other underground storage structures. Sprinkler-irrigated alfalfa fields in sandy soils are among the best pocket gopher habitats. In most areas, the addition of hydraulic structures and irrigation systems will enhance the suitability of the habitat for pocket gophers. Normally, only one species of pocket gopher is found in each locality. Soil factors are important in limiting distribution. The larger pocket gophers (*Geomys* and *Pappogeomys*) tend to be restricted to the sandy and silty soils east of the Rocky Mountains. Smaller pocket gophers of the genus *Thomomys* seem to tolerate a wider variety of soils.

Pocket gophers are strictly herbivorous; any animal material in their diet appears to result from incidental ingestion. During the growing season, most feeding activity is on the surface of the ground. Pocket gophers seem to prefer forbs (broad-leafed weeds) when these are succulent during the growing season; during the rest of the year, they rely more on roots. Alfalfa and dandelion are apparently some of the most preferred and nutritious foods for pocket gophers. Generally, *Thomomys* prefer perennial forbs, but they will also eat annual plants with fleshy underground storage structures. Plains pocket gophers eat large quantities of grasses, especially those with rhizomes such as bluegrass and Johnson grass.

Pocket gophers do not hibernate; they are active all year and feed extensively on the surface of the ground under snow cover. This is especially true of some species of *Thomomys* in mountainous areas with deep snowpacks.
Impacts. Pocket gopher activity can be distinguished from that of other burrowing mammals by their telltale mounds and plugged burrow entrances. In areas with snow cover, the presence of soil casts after snowmelt is also indicative. Seepage on the lower sides of canal banks is often the first indication of a gopher problem.

Except for small earthen structures, pocket gopher activity is usually not a threat to the integrity of dams. However, their burrowing activity is a serious threat to many canal systems. Their burrows weaken ditchbanks, cause water loss by seepage and piping through the bank and can result in complete loss or washout of the canal bank. The potential for damage is especially high when surges caused by storms or other factors raise water levels in the canal. Often, pocket gopher burrows are just above the water level, and even a slight rise may result in increased seepage, piping, or washouts. In addition, the presence of pocket gophers increases the likelihood of badger activity, which can also cause damage.

Pocket gophers can also damage underground irrigation pipes, as well as electrical or communication cables, including those used for control of headgates or other water control structures. In addition, they may alter the vegetative composition along canal banks by smothering vegetation with their earthen mounds, thereby providing a seedbed for invading annual weeds.

With the obvious potential pocket gophers have for causing damage, especially to canal banks, sustained control efforts to keep their populations to a minimum should be cost beneficial.

5.5.3.1.1 Legal status

Pocket gophers generally are not protected by Federal or State laws and are considered a pest in most states where they occur. However, check with your local authorities. There is an attempt to list the Douglas County Pocket Gopher (*Thomomys talpoides macrotis*), which is limited to the front range of Colorado.

5.5.3.1.2 Control methods

Exclusion. Concrete-lined canals provide excellent protection from pocket gopher damage but are expensive and not completely immune. Barriers, such as a concrete wall or impervious soil wall incorporated in the canal bank, have also shown some effectiveness but are relatively expensive to install, especially in existing old canal banks that contain large rocks.

Fencing has limited use for protecting hydraulic structures, because of expense and impracticality. To keep pocket gophers out, fencing must be buried at least 50 cm (20 inches) and extend 15 to 20 cm (6 to 8 in) above ground.

Buried utility cables can be protected by placing them inside plastic pipes with outside diameters exceeding 5.5 cm (2.2 in). Large diameters like this essentially present a flat surface to most pocket gophers; they cannot open their mouth wide enough to bite into them. Another method is use of gopher-resistant armored cable.

Cultural Control. Management of most irrigation systems includes some weed control, and this can also be effective in controlling damage by pocket gophers. Chemical or mechanical control of forbs, especially those that have large underground storage structures, can reduce pocket gopher use of areas, especially by the genus *Thomomys*. Pocket gophers will thrive on rhizome-forming grasses, such as bluegrass or Johnson grass, but if weed control results in increased coverage with bunch grasses, this can further reduce their use of the area. In central and eastern Washington, they are essentially absent on canals with such grass stands. This method is less effective for pocket gophers of the genera *Geomys* and *Pappogeomys*. Bare ground will also discourage pocket gophers but may lead to erosion.

Chemical Control. Several rodenticides are registered and available for pocket gopher control. The most widely used is strychnine alkaloid (0.25 to 0.5 percent active ingredient [ai]) which is registered for use with *Geomys* spp. and *Thomomys* spp.; grain baits containing 0.3 to 0.5 percent ai are available in most States. Zinc phosphide baits (usually containing 2 percent ai) also are available in some States but are less effective than strychnine for most pocket gophers. Anticoagulant chlorophacinone baits (0.005 percent ai) are available for controlling pocket gophers, but only in a few States and only by hand baiting. Consult your State Director for Wildlife Services, USDA/APHIS, for details on toxicants that can be used in your State and on sources of supply.

Several registered fumigants are available and include aluminum phosphide and gas cartridges ("smoke bombs") with various ai. These materials are not very successful when used to control pocket gophers because gophers have extensive, shallow burrow systems and will readily seal off individual burrows. Unless the soil is moist, the fumigant will diffuse through the soil out of the gopher’s tunnel.

To poison pocket gophers, the bait must be placed in their tunnel systems by hand or by a special machine known as a burrow builder. Underground baiting for pocket gophers with strychnine presents minimal hazards to nontarget wildlife, either from eating the bait or from eating poisoned pocket gophers. However, if strychnine bait is spilled on the surface of the ground, it may be hazardous to seed-eating birds such as doves.

Toxic bait can be placed in a burrow by hand or with a special hand-operated bait dispenser, by making an opening to the burrow with a probe or by excavating the burrow and placing bait in it by hand. Excavation is more time consuming than any probing method but leaves no doubt that the bait has actually been placed in the gopher's burrow.

The key to effective pocket gopher baiting is locating the underground burrow. The main burrow is usually found on the plug side of the fan- or kidney-shaped mound a short distance away. If excavating, dig down to the burrow, place the proper amount of bait well into the burrow with a long-handled spoon, and close the burrow again with soil or a sod clump. If using a probe or bait dispenser, locate the burrow, release the metered bait amount (from the dispenser) or place the proper amount of bait down the hole, and cover the probe hole with soil or a sod clump. (Burrows should be closed because pocket gophers will plug any open burrows they find and could cover the bait.) It is not necessary to bait all mounds; usually bait placed at two to four places in each burrow system will give good results. Along canals, baiting at intervals of about 6 to 8 m (about 20 ft) is usually, adequate.

The best way to treat large areas economically is with the burrow builder. This device constructs an artificial underground burrow and places bait in it. The artificial burrows intercept the natural burrows; the gophers readily use the artificial burrows as part of their system and, in doing so, find and eat the bait.

Burrow builders are tractor drawn and available with a trailer-type or three-point hitch. They may be bought from the manufacturer (Elston Equipment Co., Minneapolis) or farm machinery dealers. They are sometimes available for rent or loan through county agents, agricultural organizations, or the State Director for Animal Damage Control, USDA/APHIS.

For best results, the artificial burrows should be placed about 6 to 7.5 m (20 to 25 ft) apart and at depths similar to those made by pocket gophers in the area. Usually, most natural burrows will be less than 30 cm (12 in) deep.

Adequate soil moisture is necessary to construct good, relatively clean artificial burrows. If the soil is too dry, a burrow will not be formed; if it is too wet, the torpedo will not scour and the soil may not close over the burrow. Usually, if a ball of soil compresses in your hand and can be rolled gently around without crumbling, moisture is adequate. Another indicator is good plowing conditions.

Obviously, soil types vary drastically; in some soils, good artificial burrows are difficult to construct under any circumstances; but in most areas with pocket gophers, soil moisture will be adequate at some time during the year.

Mechanical Control. Trapping is an effective method for controlling pocket gophers on small areas and to remove surviving animals after a control program. It is too labor intensive for most general control programs.
Differences in species, soil types and moisture, and time of year all affect the vulnerability of pocket gophers to traps. It is usually better to set traps in the main burrow. Several types of gopher traps are available. Consult your State Director for Wildlife Services, USDA/APHIS, for recommendations on trap type and placement.

Trap locations should be marked with flags above ground, and traps should be anchored to prevent the gophers from dragging them away. If gophers do not visit a trap within 48 hours, move it to a new location. In spring and early summer (longer in southern areas) during the breeding season and when young are in the parental burrow, leave traps in the burrow another day, even if a gopher has been caught; you may catch another one.

Trapping can be done year-round because pocket gophers are always active, but it may be impractical when the soil is frozen or extremely dry and hard. It is much easier to trap when the soil is moist and digging is easier. Trapping is most effective when gophers are building new mounds, especially in spring and fall. Shooting pocket gophers is impractical because they spend most of or their time below ground.

Bounties are often mentioned as a means of pocket gopher control. Bounties paid for pocket gophers are essentially useless for controlling damage to agricultural crops and do nothing to reduce damage to hydraulic structures. Trapping for bounties is usually done where gophers are most easily caught, not where the potential for damage may exist, and trapping efforts usually stop when the catch starts to decline, leaving many animals behind. Funds expended for bounties would be much better spent on a control program using the methods described above.

Ultrasonic devices, though widely promoted for rodent control, have been shown to be ineffective for pocket gophers in field applications.

5.5.3.2 Ground squirrels (Sciuridae)

Identification. Ground squirrels are small to medium-sized burrowing rodents of the genus *Spermophilus* in the family *Sciuridae*.

There are 22 species of this genus in North America they vary greatly in size, with lengths ranging from 15 to 50 cm (6 to 20 in) and weight ranging from near 100 to over 1,000 g (0.25 to over 2.5 lb). They also vary in color, ranging from gray to brown to reddish brown. Some species have spots, others have stripes, and some have both spots and stripes. Some species have short tails with relatively short hair, while others have long bushy tails similar to those of tree squirrels of the genus *Sciurus*.

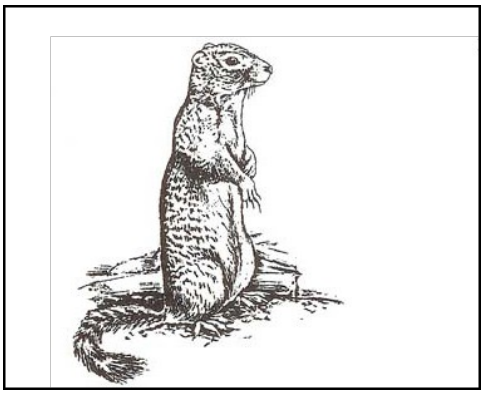

Figure 5.5.3.2.—Ground squirrel.

Ecology. Ground squirrels occur in Western North America in at least 27 States and 7 Canadian provinces, from the arctic to the desert areas of the Southwestern United States and Mexico, and to the gulf coast in Texas and Mexico. They range as far east as Ohio but are not found in the Northeastern or Southeastern United States. The 17 species that are found in the United States are variable in their distribution, as noted below.

The California ground squirrel (*Spermophilus beecheyi*) occurs in California, as you would expect, and also in western Oregon, southcentral Washington, extreme western Nevada, and south into Mexico. The Columbian ground squirrel (*Spermophilus columbianus*) occurs in western Montana, north into Alberta and British Columbia, eastern Washington and Oregon, and in northern and central Idaho. Franklin's ground squirrel (*Spermophilus franklinii*) occurs on the northern Great Plains and east and south into Indiana, Illinois, and Missouri. The Mexican ground squirrel (*Spermophilus mexicanus*) occurs in western Texas, in extreme southeastern New Mexico, and in Mexico.

The 13-lined ground squirrel (*Spermophilus tridecemlineatus*) occurs throughout the Great Plains and from Ohio on the east to Utah on the west and from the Canadian provinces to the gulf coast in Texas. Townsend's ground squirrel (*Spermophilus townsendii*) essentially occupies the Great Basin. The round- tailed ground squirrel (*Spermophilus tereticaudus*) occurs in the far southwestern portion of the United States and into Mexico.

Richardson's ground squirrel (*Spermophilus richardsonii*) and the similar Wyoming ground squirrel (*Spermophilus elegans*) range widely in the northern portions of the Western States.

The Belding ground squirrel (*Spermophilus beldingi*) occurs in western and southern Oregon, northwestern California, northern Nevada, southwestern Idaho, and extreme northwestern Utah. The spotted ground squirrel (*Spermophilus spilosoma*) occurs on the Great Plains from South Dakota south to the gulf coast and into Mexico, and from western Texas west into Arizona and southeastern Utah.

Ground squirrels occupy a wide variety of habitats, soil types, and conditions, from low coastal areas to high mountainous areas. Various species may be found in forest, grassland, shrubland, desert, wetland, and cultivated areas. In fact, the only habitats in the West where ground squirrels are not expected are water sites. Normally, only one or two species of ground squirrel are found in each locality.

Some species of ground squirrels are solitary; others are colonial, with several individuals living in the same burrow system. Densities reported for ground squirrel species are highly variable. Burrow design varies with the species, soil type, habitat, and climate. Depth may range as deep as 3 m (9 ft). Diameter varies with the body size of the species and may range from 5 to 25 cm (2 to 10 inches).

Ground squirrels hibernate in winter, and most species estivate in summer as well. Dormant periods vary with the species, age, sex, and environmental conditions. Ground squirrels are active only in daylight. They are most active during pleasant weather, and during midmorning and late afternoon, usually avoiding midday heat. Most species have one litter per year, but breeding seasons may be prolonged, again depending on environmental conditions. As with most rodents, litter sizes range from 1 to 10 but usually average 3 to 7.

Numerous bird, mammal, and reptile predators eat ground squirrels. Most pursue them on the surface, but a few, including snakes, weasels, coyotes, and badgers, take them in their burrows as well. As with pocket gophers, badgers are an important predator and can cause considerable damage when digging for ground squirrels.

Ground squirrels are generally considered herbivores, but some species also eat insects, eggs, carrion, and other animal material. The parts of plants eaten vary seasonally. When ground squirrels first come out of hibernation in spring, they eat green and succulent vegetation. As the season progresses, mature plants and seeds become more important. Crop damage can occur any time they are active.

Impacts. Unlike pocket gophers, ground squirrels keep their burrows open. Burrows of solitary species tend to be scattered and inconspicuous. Burrows of colonial ground squirrels resemble those of prairie dogs, including the presence of mounds, and are of much more concern around hydraulic structures. When

colonial ground squirrels are present in the area, they are easy to see during their active periods.

Ground squirrel activity can seriously damage canals and can even be a threat to the integrity of small dams. Their burrows weaken ditchbanks, cause water loss by seepage and piping through the bank and can result in complete loss or washout of the canal bank. As usual, the potential for damage is higher when storms or other surges cause changes in water levels in the canal. In addition, the presence of ground squirrels increases the likelihood of badger activity, which can also cause damage. Ground squirrels can alter the vegetative composition along canal banks, and their mounds provide a seedbed for invading annual weeds.

With the obvious potential that some species of ground squirrels have for causing damage to both canal banks and small dams, control efforts to keep their populations to a minimum should be cost beneficial.

5.5.3.3 Legal status

Most ground squirrels are not protected by federal or State laws and are considered pests or nongame species. They are protected by some State and provincial regulations. One species, the Mohave ground squirrel (*Spermophilus mohavensis*), which has a limited distribution only in California, is endangered. Species that damage agricultural crops and hydraulic structures can legally be controlled in most States.

5.5.3.4 Control methods

Exclusion. Concrete-lined canals provide excellent protection from ground squirrel damage but are expensive and not completely immune.

Fencing is generally expensive and impractical for protecting hydraulic structures from ground squirrel damage.

Cultural Control. Routine weed control can have some effect in limiting use of canal banks by ground squirrels, but it does not reduce their populations as much as it does with some pocket gophers.

Flooding and frequent tillage may discourage ground squirrels in some areas.

Chemical Control. Zinc phosphide-treated baits can be applied by hand in, or broadcast on, noncrop areas such as rights-of-way, golf courses, ornamental plantings, lawns, field borders, and ditchbanks. Aluminum phosphide tablets and pellets can be used to treat 13-lined ground squirrel burrows in agricultural and noncropland areas. Baits can be placed by hand or mechanically dispensed; in some States, they may also be spread by aircraft. Consult your State Director for Wildlife Services, USDA/APHIS, for details on toxicants that can be used in your State and on sources of supply.

Several registered fumigants are available and include aluminum phosphide, carbon disulfide, and gas cartridges (“smoke bombs") with various ai. While fumigants may cost more to treat a colony of ground squirrels than baiting, fumigants are convenient and relatively safe to use, and the gas cartridges are not a restricted-use pesticide. Aluminum phosphide comes in a tablet or pellet form that can be applied into burrows with a dispenser or by hand with gloves. The hole is then plugged tightly with sod or newspaper and soil. Gas cartridges are ignited with a fuse and inserted in the burrow and the hole is then plugged tightly. Care should be taken to ensure that the fumigant is not smothered with soil.

Fumigants should be applied when the soil is moist because the moisture helps seal the fumigant in the burrow system; in the case of aluminum phosphide tablets, adequate soil moisture is necessary to release the gas.

Mechanical Control. Trapping is useful only for removing small populations of ground squirrels in especially critical areas or for final mop-up operations after a control program. It is too labor intensive for general use. Leg-hold traps (No. 1 or 0), cage traps, or burrow-entrance live traps can be used. Flooding burrows with water will enhance the effectiveness of trapping and snaring.

Shooting may provide some control in limited areas or for final mop-up, but it is expensive and time consuming. Shooting may provide traditional recreation but should not be used as the primary method of control. A valid State hunting license may be required.

Ultrasonic devices, though widely promoted for rodent control, have repeatedly been shown to be ineffective against ground squirrels in field applications.

5.5.3.5 Prairie dogs

Identification. Prairie dogs are burrowing rodents of the genus *Cynomys* in the squirrel family *Sciuridae*. There are four species, all found in the Western United States. Prairie dogs are squirrel-like with sturdy, squat, muscular bodies and short tails and ears. Their legs are short and muscular and are well adapted for digging. Body length for adults is 30 to 40 cm (13 to 17 inches) with tails that are an additional 6 to 10 cm (2 to 4 inches). Weights are 0.8 to 1.7 kg (2 to 4 lb). Hair is rather coarse with little underfur and ranges in color from sandy brown to cinnamon with grizzled black and buff-colored tips. Tail tips are black in two species and white in two species. Prairie dogs got their names from their wheezing bark and various warning chirps. They are highly sociable and generally live in well- defined colonies.

Figure 5.5.3.5.—Prairie dog.

Ecology. The black-tailed prairie dog (*Cynomys ludovicianus*) is the most widely distributed species and occurs essentially throughout the Great Plains. The white-tailed prairie dog (*Cynomys leucurus*) is found mostly west of the Continental Divide in the Great Basin. The Gunnison prairie dog (*Cynomys gunnisoni*) occurs in the Southwest. The Utah prairie dog (*Cynomys parvidens*) occurs only in Utah; it is classified as an endangered species.

All four species are found in grassland or short shrubland habitats. They prefer open areas of low vegetation, generally semi-arid rangelands with short, mixed, or mid-height grass. They prefer to establish colonies near intermittent streams, old buffalo wallows, temporary rain catch basins, water impoundments, old fields, homestead sites, windmills, and similar situations. They do not tolerate tall vegetation well and avoid brush and timbered areas. Heavy livestock grazing, compounded by dry years, seems to enhance prairie dog expansion. Wet years with abundant vegetative growth on rangeland seem to have the opposite effect.

Prairie dogs are largely herbivorous and eat mostly grass. Black- tailed prairie dogs on native shortgrass prairie in Colorado have been shown to eat about 70 percent grass. Within prairie dog colonies, especially dense ones, grasses are often reduced and various annual forbs become more abundant. The impact of prairie dogs on native and domestic grass pastures varies with the soil type, plant species, intensity of use by domestic animals, and other factors, but is often severe. For example, observations of prairie dog invasion and use of grasslands in Colorado showed that prairie dogs removed up to 90 percent of total forage and completely eliminated grass on much of the area they populated. Forbs, which have limited grazing value for livestock or prairie dogs, often then became plentiful.

In addition to grass, prairie dogs eat seeds, succulent leaves, stems, and roots of various plants. They also feed on grasshoppers and other insects during the summer months.

Considerable effort has been devoted to studying the biology, life history, benefits, and costs of prairie dogs. They have an interesting social organization and live in colonies called "towns." The colonial habit is most highly developed in the black-tailed prairie dogs. The other species live in more dispersed associations and lower densities. Black-tailed prairie dog colonies may contain up to 150 individuals per ha (60 per acre) during June and July. Burrows generally number in the same range with varying degrees of use during the year.

Black-tailed prairie dogs are active during mild weather year-round. The other species have relatively long periods of inactivity during winter, especially during severe weather. Prairie dogs have one litter per year and produce four to eight young in the spring (April to June). The young disperse and make their own burrows within a few months. Numerous bird, mammal, and reptile predators eat ground squirrels. Most pursue them on the surface, but a few, including coyotes, badgers, and snakes, take them in their burrows as well. Prairie dog colonies seem to be the key to the continued existence of the black-footed ferret (*Mustela nigripes*), an endangered species.

Impacts. Prairie dogs clip and remove vegetation from the vicinity of their burrows to use as food or nesting material. They also apparently cut vegetation within the colony to maintain visibility or to remove cover that might hide predators. This can cause substantial changes in plant species composition; because prairie dogs crop the vegetation so closely, there is often little left for livestock.

Prairie dog burrowing results in relatively large holes and cone-shaped mounds. Their burrows have been found almost 4.6 m (15 ft) below the surface. Materials they bring up from such depths are poorer soils and subject to wind and water erosion. Additionally, plants are slow to establish on the poor soil of prairie dog mounds.

Where prairie dogs become established in flood-irrigated fields, water is lost as it drains into their burrow systems, and parts of the field may be lost. Prairie dogs can cause severe damage to ditchbanks and small earthen dams. They probably do not threaten the integrity of large dams, but they may interfere with foot drains or other structures in some larger earthen dams. Prairie dog activity can also undermine roads and trails associated with hydraulic structures. As with pocket gophers and ground squirrels, some habitat manipulation and sustained population control will usually keep prairie dog problems to a minimum. However, if the problem area is within the range of the black-footed ferret, control efforts may have to be restricted.

5.5.3.6 Legal status

The listing status for the prairie dog is a rapidly changing situation. For further information on the status of the prairie dog and legal requirements, consult the USFWS, or your State Director for Wildlife Services, USDA/APHIS.

5.5.3.7 Control methods

Prairie dog control can be a very controversial issue and may need to be discussed with other local entities.

Exclusion. Exclusion of prairie dogs is rarely practical and probably of little use for hydraulic structures.

Cultural Control. Plowing and keeping land fallow will reduce prairie dog numbers. The development of tall vegetation, such as crested wheatgrass or grain crops, will discourage use or invasion by prairie dogs. However, in areas where maintenance of tall vegetation is difficult at best, prairie dogs will invade and use such areas in spite of management practices. Heavy grazing by livestock also may result in establishment of prairie dogs. Limiting grazing can reduce the potential for prairie dog invasion. Managers may need to include prairie dogs in the calculation for cattle stocking rates to ensure that overgrazing does not occur. Summer consumption rates range from 30 to 100 g (1.05 to 3.5 oz) of green forage per prairie dog per day.

Chemical Control. Baiting with a toxicant is usually the most practical and economical method for reducing or eliminating prairie dog colonies. The availability of toxicants varies with Federal and State registrations. Zinc phosphide bait (at 2 percent on an oat bait) is effective, but prebaiting is necessary to achieve maximum control. Zinc phosphide bait is relatively safe regarding livestock and other wildlife in prairie dog towns. Bait must be placed in burrows or it will kill other nontarget birds and mammals.

Prebait and bait is normally placed by hand on the edge of each mound where bare soils meets grass. Do not place bait on top of the mound or down the burrow. Thinly scatter the treated bait in a 15-cm (6-inches) bait spot during early morning. Avoid placing treated bait in piles that may endanger livestock.

Consult your State Director for Wildlife Services, USDA/APHIS, for details on toxicants that can be used in your State and on sources of supply. See “Prairie Dogs” at the University of Nebraska Extension Service Web site: http://lancaster.unl.edu/ag/crops/wildlife.shtml for detailed damage prevention and control methods.

Several registered fumigants are available and include aluminum phosphide and gas cartridges ("smoke bombs") with various ai. While fumigants may cost more to treat a colony of prairie dogs than baiting, fumigants are convenient and

relatively safe to use, and the gas cartridges are not a restricted- use pesticide. Aluminum phosphide comes in a tablet or pellet form that can be applied into burrows with a dispenser or by hand with gloves. The hole is then plugged tightly with sod or newspaper and soil. Gas cartridges are ignited with a fuse and inserted in the burrow, and the hole is then plugged tightly. Care should be taken to ensure that the fumigant is not smothered with soil. Fumigants should be applied when the soil is moist because the moisture helps seal the fumigant in the burrow system; in the case of aluminum phosphide tablets, adequate soil moisture is necessary to release the gas.

Mechanical Control. Trapping is useful only for removing small populations of prairie dogs in especially critical areas or for final mop-up operations after a control program. It is too labor intensive for general use. Several traps can be used, including cage traps for live capture, Conibear traps (No. 120), and leg-hold traps (No. 1). Live trapping and relocation may be necessary in some locations.

Shooting prairie dogs is seldom practical as a primary management tool for preventing damage to hydraulic structures. A valid State hunting license may be required.

Ultrasonic devices, though widely promoted for rodent control, have repeatedly been shown to be ineffective against species on which they were field tested and can probably be considered ineffective for all field applications.

5.5.3.8 Voles (Microtus), rats (Rattus), mice, and chipmunks (Eutamias)

Identification. Of these animals, the group that causes the most concern for hydraulic structures is voles (meadow mice) of the genus *Microtus*. These are dark, compact, mouse-like rodents with short legs and tail.

Rats of the genus *Rattus* are easily recognized as typical rats, but there are also pack rats (*Neotoma* spp.), which have big ears, hairy tails, and pale underparts; cotton rats (*Sigmodon* spp.), which look like large voles; and kangaroo rats (*Dipodomys* spp.), which are strikingly marked jumping rodents with long, tufted tails.

Mice include many species of several genera. Mice can be destructive to property, and the primary health concern is the Hanta virus transmitted by the deer mouse.

Chipmunks (*Eutamias* spp.) are small squirrel-like rodents with bushy tails and prominent stripes on their face and sides.

Ecology. Voles primarily live on green vegetation. They are most common in areas of dense grass, but some species can occur in drier habitats. They are active day and night year-round. They construct burrow systems of many shallow

tunnels and surface runways that may contain several adults and young. Voles are prolific; they can have up to 5 litters per year with up to 10 young per litter. Population peaks and crashes are typical of voles, with cycles occurring every 2 to 5 years. During extreme peaks, population levels of 10,000 per ha (4,000 per acre) have been recorded. When populations crash, it is hard to even find one. These rodents are found in a variety of areas throughout the United States and have a variety of lifestyles. Since they are rarely involved in damage to hydraulic structures, details of their ranges, habitats, and general biology will not be discussed. Certain species of mice can carry the hanta virus, a human health hazard. See the following Web site developed by the U.S. Department of Defense for more information: www.acq.osd.mil/eie/afpmb/.

Impacts. Vole activity is easily identified by the animals' extensive surface runway systems and numerous burrow openings. This activity is only a problem to hydraulic structures when the population is very high, and even then, only small berms and very small canal banks are threatened.

Damage by other rodents in this group is sporadic and generally limited to very local situations. On the rare occasions when such rodents seem to be causing problems, ask your State conservation agency or your State Director for Wildlife Service, USDA/APHIS, for help in identifying the species responsible.

5.5.3.9 Legal status

Most of these animals are afforded no legal protection, as they are often considered pests. An exception may be the Preble's Jumping Mouse, a listed species, found along waterways along the front range of Colorado.

5.5.3.10 Control methods

Exclusion. These animals can be excluded from buildings but excluding them from hydraulic structures is generally impractical. Attempt to seal all openings for mice, rats, and chipmunks. It is recommended to protect trees, ornamental plants, small areas to exclude voles.

Cultural Control. Eliminating dense grass cover and weeds through cultivation, herbicides, etc., will discourage voles and most of the other animals in this group. Removing litter, rock piles, and other harborage will also discourage most of them. Store food items properly and reduce sources of food, water, and shelter. Dispose of refuse and control garbage areas.

Chemical Control. Toxicants have traditionally been the primary method used for controlling populations of these species. Zinc phosphide and anticoagulants can be effective if properly used. Consult your State conservation agency or your state director for Wildlife Services, USDA/APHIS, for details on toxicants that can be used in your State, as well as sources of supply.

Fumigants are impractical for controlling voles, mice, and chipmunks; however, they can sometimes be effective for controlling rats (*Rattus* spp.) in outdoor burrows. Contact your state director for Wildlife Services, USDA/APHIS, for details on fumigants.

Mechanical Control. Trapping is impractical for controlling these species, except to remove a few individuals; however, with rats, a few individuals may be all that are present and causing problems around hydraulic structures, so this method may be useful at times. A variety of rat traps are effective, including snap traps, box or cage traps, and many less traditional types.

Other Methods. While some repellents are effective for protecting orchard trees from voles, none are practical for use around hydraulic structures. This is also true for the other animals in this group.

Though widely promoted for rodent control, ultrasonic devices have repeatedly been shown to be ineffective against species on which they were field tested and can probably be considered ineffective for all field applications.

5.5.3.11 Muskrats (Ondatra zibethicus)

Identification. Muskrats (*Ondatra zibethicus*) are semi-aquatic rodents and are well adapted for swimming. Their large hind feet are webbed, and their long tail is laterally flattened. Their front feet are smaller than their hind feet and are used primarily for digging and feeding. They have small eyes and short rounded ears. They vary in color from dark tan to reddish brown to almost black; the belly fur is always lighter. Average adults weigh slightly over 1 kg (about 2.5 lb).

Ecology. With a few exceptions (notably parts of California, Texas, and Florida), muskrats are found essentially throughout the United States.

Muskrats are limited to wetland areas but can survive in almost any place where water and food are available year-round. In marsh areas, they typically construct conical-shaped houses of plant material. In canal systems and around hydraulic structures, they dig and use burrows instead of houses for their dens.

Muskrats are primarily vegetarians and will eat most aquatic plants. Preferred foods include cattail, bulrush, smartweed, sedges, young willow, and, in some areas, agricultural crops. They will also feed on mussels, frogs, and fish, especially where preferred vegetation is scarce.

In marsh areas, muskrats' conical-shaped houses are classic evidence of their presence. They also create typical runs or trails in marshes and often make feeding platforms, which are simply floating rafts of vegetation.

Muskrats are very prolific; a female can produce 5 or 6 litters a year. Average litter size is about 6 young but varies greatly. Muskrats, especially the young, are subject to predation by several mammalian predators and birds of prey.

Impacts. Muskrat activity can threaten the integrity of canal banks and small dams. They dig relatively large burrows, but these may be difficult to detect because their entrances are below the normal waterline. Other signs of muskrat activity include trails where they come out of the water and droppings along the bank or on structures they can easily climb on. In rice growing and aquaculture areas, they can cause extensive damage to levees and disrupt proper water levels, as well as destroy substantial amounts of rice by eating it or cutting it to make houses.

In other areas (small farm ponds, for example), the value of the muskrat population as a fur resource may outweigh the damage caused; however, in many canal systems, the potential threat of a major canal break caused by muskrats will usually justify control efforts.

5.5.3.12 Legal status

In most areas, muskrats are classified as a furbearer. In fact, nationally they are the most important furbearing mammal. States have varying regulations regarding control of muskrats. Consult your state conservation agency or your State Director for Wildlife Services, USDA/APHIS, before undertaking any direct muskrat control activities.

5.5.3.13 Control methods

Exclusion. A barrier of stone riprap will usually prevent muskrats from burrowing into the dam. Concrete-lined canals are relatively immune to damage by muskrats. While fencing may be useful to protect some crops from muskrats, it is not practical for most hydraulic structures.

Cultural Control. Probably the best method of control is the reduction or elimination of aquatic vegetation or other plants eaten by muskrats. Herbicides are commonly used to control aquatic vegetation, and, more recently, the use of grass carp (*Ctenopharyngodon idella*) is showing promise. Vegetation control is often recommended for other purposes like improving waterflows; using it for controlling muskrat damage is further justification.

Chemical Control. Consult your state director for Wildlife Services, USDA/APHIS, for details on toxicants that can be used in your state and on sources of supply (for addresses, see the Appendix).

Mechanical Control. Muskrats are one of the easiest furbearers to trap, and several traps can be used. Most common are leg-hold traps (No. 1 to 2) and Conibear traps (No. 110). The most effective trap sets are those placed in runs or trails where the animals' feet touch the bottom on the way in and out of the burrow and set right at the burrow entrance. Recent legislation in some States has placed restrictions on leg-hold traps or, in some cases, made them illegal. Leg-hold traps may not be an acceptable control method in many Reclamation offices. Check the regulations in your area before trapping.

Shooting is feasible where it is legal and safe but too labor intensive to use as a primary control method. A valid state hunting license may be required.

5.5.3.14 Beaver (Castor canadensis)

Identification. The beaver (*Castor canadensis*) is the largest rodent in North America. Most adults weigh between 15 and 22 kg (about 35 to 50 lb), but some have been recorded up to 45 kg (100 lb). They are well suited for an aquatic environment with large, webbed hind feet and a large flattened tail. The tail is used for swimming, for communication while in the water, and as a prop when sitting upright. The front feet are small in comparison to the hind feet. Beavers vary somewhat in color, reddish-brown is most common. The belly fur is usually gray.

Ecology. Beavers are found throughout North America, except for the arctic tundra, most of Florida, and Southwestern deserts.

Beavers will occupy almost any area with a year-round source of water. Where there is a source of running water, they cut trees and other woody vegetation, build dams, and flood large areas, which can drastically alter the habitat.

Beaver activity can provide a year-round source of water where it previously was intermittent; thus, they create and maintain their own habitat and contribute to raising of the water table and creation of habitat for other, sometimes sensitive, species.

Beavers prefer certain trees and woody plants such as aspen, cottonwood, and willow; however, they will eat the leaves, twigs, and bark of most woody species that grow near the water. They also eat a wide variety of aquatic and other herbaceous plants.

Beavers are renowned for their dam building abilities, but they also build lodges and bank dens. Beavers are adaptable and will use whatever construction materials are available, including rocks, wire, wood, crop residues, and a variety of herbaceous plants.

For rodents, beavers have a relatively long lifespan of several years. They become sexually mature at about 1.5 years. There is usually only one litter of three or four young per year. Beavers are territorial and live in colonies with four to eight related individuals. Young are often displaced shortly after they mature sexually and move to other areas where they may create new ponds.

Young beavers may be taken by river otter and mink, but adults are taken only by large mammalian predators.

Impacts. Most damage caused by beavers is the result of dam building, tree cutting, bank burrowing, or flooding. Usually, identifying beaver damage is not difficult. In reservoirs, bank burrowing may result in failure of the dam.

Beaver dams across spillways can result in flooding, failure of the spillway, or failure of the entire structure. Beaver activity in and around canals, culverts, drain pipes, flood channels, and bridges can literally make the structure useless. The removal of sticks, logs, debris, and accumulated mud can be extremely difficult.

Even limited beaver activity can restrict waterflows, which may go unnoticed until critical or emergency situations develop.

Since beavers are a valuable fur resource, there will always be some pressure to manage them as a fur animal. However, major flooding, failures of dams and canal banks, disruptions of normal streamflows, and clogging of drainage and emergency flood channels are all possible results of beaver activity; therefore, beaver control efforts are appropriate in and around some hydraulic structures.

5.5.3.15 Legal status

Beavers are classified as a furbearer in many States. Because of their fur value and the water conservation that results from their dam building, they are not usually considered a pest unless extensive damage occurs. Check with your state conservation agency or your State Director for Animal Damage Control, USDA/APHIS, before undertaking any direct beaver control activities.

5.5.3.16 Control methods

Exclusion. Fencing has only limited value in keeping beavers from culverts, drainpipes, or other structures and sometimes becomes part of the beaver's construction material.

Cultural Control. Unless beaver food sources or the aquatic habitat can be eliminated, most cultural practices have little impact on beavers. Wrapping tree bases with chain link fence has been effective to keep beavers from damaging

larger trees. They alter their aquatic habitat so extensively that most cultural practices are ineffective however. Their dams or plugs in waterways can be removed, but the beavers will usually quickly replace them.

Mechanical Control. The use of traps is usually the most effective means of removing beavers where they are causing damage. Several types of traps are suitable, including Conibear (No. 330), leg-hold (No. 3 double spring is a minimum), and a suitcase-type cage trap designed for live capture. The effectiveness of any trapping program depends on trap placement and the trapper's experience and knowledge of beaver habits. Most beavers can be trapped using dam sets, lodge or den sets, or sets in runs or trails. Dam sets usually involve removing a portion of the dam so that water flows through it; when the beaver attempts to repair the area it is caught in the trap. State regulations vary, and some traps and methods may not be legal in your area; consult your State conservation agency or your State director for Wildlife Services, USDA/APHIS, for advice and help with beaver trapping.

Where legal and safe, shooting can be effective in removing beavers after a trapping program. By itself, shooting is not very cost effective. A valid State hunting license may be required.

Other methods. No toxicants, fumigants, or repellents are available for beaver control. Dynamiting of lodges and dams has been used but usually only in emergency situations.

5.5.3.17 Nutria (Myocastor coypus)

Identification. Nutria (*Myocastor coypus*) are large brownish or blackish semi-aquatic rodents that are about midway in size between muskrats and beavers. Large males may weigh 9 kg (20 lb) but the average adult weighs about 3.5 kg (8 lb). Nutria are easily identified by their prominent, red-orange incisors and long whitish whiskers. They have short front legs with strong claws. Their hind legs are longer, and the hind feet are webbed. Their tail is long, dark, and round. They are excellent swimmers but are somewhat cumbersome on land.

Figure 5.5.3.17.—Nutria (Photo by Justin Secrist, USDA).

Ecology. Nutria were imported as fur animals into the United States from South America starting around 1900. They became established as wild populations in over half of the States. While some populations have died out, wild populations are still found in over 20 States, most commonly in the Southeast and in some river systems in the Pacific Northwest. Nutria distribution in the United States seems to be limited by cold climates. A range map is not given because the exact distribution of United States nutria populations is not well defined.
Nutria are generally restricted to wetland areas such as marshes, rivers, creeks, and canal systems.

Food Habits. Nutria are strictly herbivorous, living mainly on the succulent parts of sedges, rushes, cattails, and other aquatic plants. In agricultural areas, they will feed on crops such as sugarcane and rice.

During the warm months, nutria may live on the ground in dense vegetation, but, at other times of the year they often use burrows. They may dig their own burrows or use those of other animals such as muskrats, armadillos, or beavers. The burrow may house a single nutria or a family group.

Nutria are quite prolific and have young throughout the year. Litter size varies from one to nine but averages about five. They can be sexually mature at 4 to 6 months. The female's mammary glands are located on her back, which allows the young to nurse while she is swimming.

Nutria build platforms of vegetation for feeding, resting, nesting, or for protection from predators and bad weather.
Impacts. Nutria burrows are large enough to threaten the integrity of major canals and ditchbanks. Their burrows are usually at or near the waterline, and often in dense vegetation, so they may be hard to find. In rice-growing areas, nutria burrows can cause breaks in levees that regulate water levels.

Nutria are a valuable fur resource in the Southeast and trapping for fur may keep most populations at a level that presents little risk to hydraulic structures. In rice-growing areas, sustained control efforts may be required to maintain levees and appropriate water levels. In other parts of the country, vegetative management should reduce the potential for nutria damage.

5.5.3.18 Legal status

Nutria are usually considered non-game animals or pests but are classified as furbearers in some States. Check with your state conservation agency or your state director for Wildlife Services, USDA/APHIS, before undertaking any direct nutria control activities.

5.5.3.19 Control methods

Exclusion. The use of fences or other barriers is not practical for controlling nutria damage.

Cultural Control. Mowing of vegetation, brush removal, and weed control will remove much of the food and cover used by nutria. Well-managed canal systems where this is done should have few problems with nutria damage.
Chemical Control. Check with your State conservation agency or your State Directory for Wildlife Services, USDA/APHIS, for details on toxicants that can be used in your State and on sources of supply.

Mechanical Control. Trapping can be useful to remove problem nutria. Leg-hold traps (No. 2 double spring) are adequate for holding nutria. Cage traps placed on floating rafts will also capture nutria. Carrot and sweet potato are good baits.

Shooting nutria is primarily useful as a follow-up method after other control efforts have reduced the population. It can be done from canal banks or from boats and is most effective at night with the aid of a spotlight. This procedure is not legal in many States. Check with your local authorities or State wildlife agency for the legality of shooting at night. A valid state hunting license may be required.

6 PESTICIDE SAFETY AND EMERGENCY RESPONSE

6.1 Introduction

This document provides safety guidelines for employing Integrated Pest Management (IPM) techniques, pesticide handling, storage, and application. It is intended to be a practical, convenient, and comprehensive reference for instructing pest managers in the safe implementation of IPM techniques and the use of pesticides on Bureau of Reclamation (Reclamation) projects. The section emphasizes safety for pesticide applicators by providing basic information for compliance with safety and health standards established by the U.S. Occupational Safety and Health Administration (OSHA) and for the general public in accordance with the U.S. Environmental Protection Agency (EPA). It is designed to be a ready reference during the planning phase of employing IPM techniques and pesticide application projects, particularly when a Job Hazard Analysis (JHA) has identified environmental, health, and safety requirements.

Necessary approval and/or permits should be obtained in States where required for application of pesticides to water. In addition, certain Federal requirements apply as well that may not be listed on the pesticide product label. Under the

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the EPA may issue emergency orders on certain pesticides to cancel or limit their use if a Federally listed species would be impacted. Users of pesticides are advised to consult with the appropriate agencies and review all available information prior to application of a pesticide within the range of a Federally listed species. See Section 7 of this IPM Manual for additional information.

Health and safety information contained in this IPM Manual are designed for Reclamation personnel and non-Reclamation personnel (e.g., cooperating water user organizations and contract employees).

6.2 Authorities and technical references

The Reclamation pesticide safety program is based on Federal laws, Executive Orders (EO), regulations, and U.S. Department of the Interior (DOI) and Reclamation policies designed to protect pesticide applicators and workers from occupational hazards. State and local laws, ordinances, and regulations, while beyond the scope of the IPM Manual, also may affect pesticide use.

The Federal directives are supported by a significant body of scientific and technical information. References for both legal authorities and technical information are found in the bibliography. See Section 7 for more information regarding pesticide regulation.

6.3 Responsibilities

Employee health and safety are a shared responsibility among managers, supervisors, and employees. Specific safety roles and responsibilities are addressed in Department Manual (DM) 485, and Reclamation Directive and Standards (D&S), SAF P01, SAF 01-01 and 01-04.

The Reclamation Commissioner is responsible for the development and implementation of a comprehensive environmental health and safety program. Reclamation managers are responsible for informing employees of, and for the enforcement of, these environmental health and safety standards. The environmental health and safety program requires the active participation of Reclamation supervisors. They must provide: (1) Training to staff in proper work practices to anticipate, recognize, evaluate, and control unsafe acts and unsafe conditions, (2) Instruction in the preparation and use of a JHA, (3) Proper Personal Protective Equipment (PPE), and (4) Investigation and reporting of accidents or incidents.

Reclamation employees must perform their duties consistent with environmental health and safety policies set forth in Federal laws and regulations, the DM, and Reclamation D&S. Employees are expected to observe all environmental health and safety regulations and comply with environmental health and safety instructions in accordance with the pesticide container manufacturer's instructions and labeling, the product Safety Data Sheets (SDS), the instructions found in this IPM Manual, and the instructions issued to them by their supervisors. Employees have a shared responsibility for their own personal safety. Employees have a responsibility to work in a manner that does not endanger other employees, the public, or property.

Corrective actions to maintain safe and healthful working conditions are to be exercised immediately. Attention must be given to:

- Requirements of the hazard communication program
- Availability of appropriate PPE
- Pesticide label and SDS instructions
- IPM plans
- Job Hazard Analyses (JHA)
- Provisions for personal hygiene and decontamination
- Recognition and treatment of pesticide poisoning
- Site cleanup
- Safe disposal of excess pesticides and empty containers for each pesticide-use activity

6.4 Pesticide basics

The three types of pesticides most frequently used in operating and maintaining water storage and distribution facilities and related lands are herbicides, algaecides, and rodenticides. Other pesticide types—including insecticides and piscicides—are also used, but less frequently.

6.4.1 Pesticide classification

When a pesticide product is registered with the EPA, its uses are classified as *general or restricted.* All pesticide products must indicate on the package label the use classification for which they are registered (see Section 7 for additional information).

Because general and restricted classifications are based on intended use and other factors, including toxicity, formulation, and accident history, similar products with different intended uses may have different classifications.

6.4.1.1 General use

The EPA will classify a product for general use when it determines that the product, when applied according to label directions, warnings, and cautions (according to common practices), will not cause unreasonable adverse effects on the environment or injury to the user.

6.4.1.2 Restricted use

If the EPA finds that, without additional restrictions, the product may injure the applicator or other persons, or unreasonably affects the environment, the product (or the uses requiring additional restriction) will be classified for restricted use. If a product is classified for restricted use because its acute dermal or inhalation toxicity presents a hazard to humans, the pesticide must be applied only by, or under the direct supervision of, a certified applicator. If the hazard includes unreasonable adverse effects on the environment, EPA may impose restrictions in addition to applicator certification. States may require certification prior to purchasing of a restricted-use pesticide. Some States have established restricted-use categories. The category may be more inclusive than EPA's.

6.4.2 Pesticide formulations

The active chemicals in pesticides (as manufactured) are often unsuitable for application until mixed with a carrier agent (e.g., water). A pesticide formulation, or formulated product, is the commercially available mixture of active and other ingredients. Some formulated products are ready for use. Others must be diluted with water, petroleum solvent, or a dry carrier before application. The most common types of pesticide formulations are discussed below. Note that their abbreviations are given; pesticide labels sometimes refer to the product's formulation by abbreviation.

6.4.2.1 Aerosols (A)

Aerosol formulations typically contain a small amount of one or more active ingredients (a.i.) and an inert or combustible gas or propellant. The most ubiquitous aerosol formulation is the ready-to-use, pressurized, household spray can that produces a fine mist of chemical, inert, or combustible gas or propellant when the plunger is pressed. In some cases, larger, commercial versions of the plunger type are available. However, in most cases, commercial aerosols are formulated for application by machines that break liquid products (atomize) into fine droplets and dispense them as mist or fog. Typically, aerosols are used to control indoor insects and outdoor flying insects.

6.4.2.2 Baits (B)

Baits are mixtures of a.i. with edible material, usually grain or dried fruit. Some are encased in wax blocks to increase their useful life. Baits are used extensively on Reclamation projects to control pocket gophers, ground squirrels, and other rodents. Usually, they are applied without further dilution or mixing.

6.4.2.3 Controlled release

Controlled release formulations control aquatic weeds by a slow release of herbicide over time. The a.i. is impregnated in matrices of a carrier substance, which may consist of elastomers (rubber) or other material. The matrix carrier gradually dissolves and releases the toxicant in small amounts. This can provide a longer control time and may reduce adverse impacts on nontarget organisms.

6.4.2.4 Crystals (C)

Crystal formulations are “grown” and packaged to specific sizes. Copper sulfate pentahydrate “Blue Stone,” an aquaticide and algaecide, is the most frequently used crystal on Reclamation projects.

6.4.2.5 Dusts (D)

Pesticide dusts consist of finely ground carrier material, such as talc, mixed with an a.i.. Most dust formulations are ready to use as purchased, although a few require further dilution with an inert carrier. They are always used in dry, direct applications. Dusts should never be mixed with liquids.

6.4.2.6 Emulsifiable Concentrates (EC or E)

Emulsifiable concentrates are formed by dissolving the toxicant, which is not soluble in water, in an emulsifying agent and an organic solvent. The resulting product is usually diluted with water to form an emulsion for application as a spray.

6.4.2.7 Flowables (F or L)

Flowables are formulations of finely ground, insoluble a.i. mixed with a liquid and other material to form a suspension. They are diluted with water for spray application. Spray tanks containing suspensions usually require continuous agitation during application.

6.4.2.8 Granules (G)

In granulated formulations, the a.i. is mixed with an inert carrier to form granules. Often, clay, ground corncobs, vermiculite, or ground walnut shells are used. The

herbicide is absorbed into the granule or coats the outside of it. Granules, which can range in size from table salt to mothballs, are ready to use from the container. As with dusts, they should not be mixed with water or other substances.

6.4.2.9 Invert emulsions

Conventional emulsions consist of oil suspended in water. An invert emulsion consists of water suspended in oil and has a milk-like consistency. Invert emulsions reduce drift from ground and aerial applications. Special application equipment must be used to apply most invert emulsions.

6.4.2.10 Liquefied gases (LG)

Liquefied gases are a.i. that are gases at standard temperatures and atmospheric pressure. They are cooled to the liquid State and packaged in pressure-resistant containers. When released to atmospheric pressure, they revert to the gaseous State. Acrolein, an aquatic herbicide and algaecide, is the most frequently used liquefied-gas product on Reclamation projects.

6.4.2.11 Pellets (P or PS)

Pellet formulations—similar to granular formulations—are formed by molding or extrusion to give them uniform size and weight. Some pellets are coated or encapsulated to provide a time-release life.

6.4.2.12 Soluble Powders (SP)

Soluble powders are dry formulations of a.i. that dissolve completely in water. Agitation may be required for initial dissolution. The amount of a.i. in an SP is usually above 50 percent.

6.4.2.13 Solutions (S)

Solutions are mixtures of one or more substances in another substance (usually another liquid) in which all the ingredients are dissolved completely. Several types of solution formulations exist, having various concentrations of a.i. All are liquid formulations of dissolved active and inert ingredients. There are known instances where adverse quality of the water carrier (high bicarbonate alkalinity) has reduced the solubility of the concentrate to some degree. Adding a little additional herbicide may help overcome alkalinity problems as long as label directions are not exceeded.

6.4.2.14 Water-soluble concentrates

Water-soluble concentrates are solutions of water-soluble a.i. in water.

6.4.2.15 High concentrates

These formulations contain large amounts of a.i., usually 8 pounds (lb) per gallon (gal) [2.0 kilograms (kg) per liter (L)] or more. They are diluted with water for spray application. The ultra-low volume concentrate materials may sometimes be applied without any further dilution. Some formulations are diluted with oil or petroleum solvents. They contain chemicals that allow them to spread and stick well.

6.4.2.16 Low concentrates

These formulations contain small amounts of a.i. (usually 1 percent or less). They are used without further dilution.

6.4.2.17 Ultra-low volume concentrates (ULV)

These highly concentrated solutions may contain a.i. alone, dissolved in petroleum solvents. Solutions are applied without further dilution. ULV solutions require special equipment to apply them at ultra-low volumes, while maintaining a fine droplet spray.

6.4.2.18 Wettable powders (WP or W)

Wettable powders are dry, finely ground material, which contains as much as 95-percent a.i.. When mixed with water, powders form a suspension rather than a solution; good agitation is necessary during application. Continuous agitation is required to maintain suspension in the spray tank. Some WP formulations may be applied as a dust, at the discretion of the applicator.

6.4.2.19 Pesticide mixtures

Two or more pesticides are applied at the same time. These mixtures may be either package mixes, wherein the manufacturer has combined two or more pesticide chemicals in one formulated product, or tank mixes, in which the user combines two or more products in the sprayer tank. Tank mixes are applied at a dosage rate that does not exceed the label instruction rate for any product in the mix when it is applied alone.

Not all pesticides work well when mixed with another; mixing two pesticides together may result in loss of effectiveness, particle precipitation in the sprayer tank, or unanticipated injury to the area being treated. For tank mixes, some product labels list other pesticides with which the product may be safely mixed. Information on tank mixes may be available from manufacturers' field representatives, university extension services, or both.

6.4.3 Herbicides

Herbicides are chemicals used to control undesirable or noxious plants. Herbicides can be formulated as a liquid, granules, or a wettable powder. They are used on Reclamation projects to control weeds on banks of canals, laterals, drainage ditches, and reservoirs; facility landscaping; and on adjacent range and grazing land. In some cases, herbicides are applied in water to control submerged or immersed aquatic plants. Herbicides are the pesticides most often used on Reclamation projects.

6.4.4 Algaecides

Algaecides are pesticides that control or inhibit algae. They are used extensively by Reclamation to reduce blockage in water distribution and drainage systems. Algaecides are used to control algal infestations in reservoirs, which impair water quality for domestic and recreational use, and they interfere with fisheries' operations.

6.4.5 Rodenticides

Rodenticides are used to control rodents. They are used on Reclamation projects to control muskrats, pocket gophers, and ground squirrels that burrow into and undermine ditchbanks, dams, other earthen structures, and facility landscaping. Rodenticides are used to suppress meadow and field mice and moles that damage crops on Reclamation lands leased to farmers.

6.4.6 Insecticides

Insecticides are substances that control insects on plants or animals or in structures. Commonly, they are used on Reclamation projects to control termites and nuisance insects (i.e., spiders and earwigs) in buildings, mosquitoes in lowland areas, grasshoppers on range lands, and a variety of other pests on facility landscaping. Insecticides are used for crop protection on Reclamation lands leased to farmers.

6.4.7 Piscicides

Piscicides, or fish toxicants, are chemicals used to control unwanted species or groups of fish. They are used in fishery management at reservoirs and in other waters under Reclamation jurisdiction. Use of piscicides requires coordination with the State fish and wildlife agency.

6.4.8 Other pesticides

In addition to the five types of pesticides listed above, a number of others are found in the chemical trade. Though rarely or never used in Reclamation projects, they include products to control other unwanted pests, such as bactericidal agents, nematicides, avicides, slimicides, fungicides, vertebrate poisons, and products that alter plant life cycles, such as defoliants, desiccants, plant-growth regulators, and products that attract or repel insects or other animals.

6.4.9 Pesticide names

Pesticides have three names for a.i.: trade or brand name of the formulated product, common, and chemical.

- Trade names are commonly registered trademarks.
- Common names—also called generic names—are official, usually internationally recognized and accepted, designations. Often, they are shorthand versions of the chemical name of the active ingredients.
- Chemical names are the scientific names of the a.i.; they are derived from the chemical structure of the chemical.

This manual stresses the need to be familiar with common names. Using common names aids in finding information on chemical effectiveness and safety, as well as in specifying products for competitive purchase.

6.5 Pesticides and human health

Active ingredients used in the manufacture of pesticides vary greatly in their toxicity and hazard to humans and warm-blooded animals. Considerable variations in sensitivity are experienced among animals. Variations require caution in extrapolating toxicity data from animals to humans.

Pesticides and other chemical contaminants can enter the body through inhalation, skin absorption, ingestion, and injection. Inhalation is the most common route of entry. However, all routes of exposure, with the exception of injection, can compound and amplify the overall exposure or body burden. Pesticides can enter the body in the form of a solid (ingestion), liquid (skin absorption), or vapors/gas (inhalation). Highly concentrated and highly toxic chemicals (especially liquids and gases) present the greatest hazard.

6.5.1 Exposure

Exposure to pesticides or other chemical contaminants can produce acute or chronic effects. Acute and chronic effects are determined by the concentration, the duration of exposure, the frequency of exposure, the chemical toxicity, and characteristics of the host.

6.5.1.1 Dermal exposure

Absorption through the skin is the second most common way people are poisoned by pesticides. Dermal or skin contact can result from splashing chemical product onto the skin or prolonged contact with PPE contaminated with pesticide or chemical product. Dermal or skin contact can occur during the handling, storing, mixing, application, and disposal of a pesticide product or waste.

The degree of hazard from dermal absorption depends on the dermal toxicity of the pesticide, extent of exposure, pesticide formulation, and part of the body exposed. In general, wettable powders, dusts, and granular pesticides are not as readily absorbed through the skin as are liquid formulations.

6.5.1.2 Oral exposure

Accidental ingestion of pesticides most often occurs via containers improperly filled with pesticides and incorrectly labeled.

6.5.1.3 Respiratory exposure

Inhalation is the primary route of exposure for pesticides. Vapors, gases, and extremely fine dust and spray particles represent the most serious respiratory exposure hazards.

6.5.1.4 Eye exposure

Pesticide exposure via absorption through the eyes occurs when pesticide product has been accidentally splashed or rubbed into the eyes. Eye protection is required when measuring or mixing concentrated pesticides. Protection is needed when one is exposed to drifts of spray or dust.

6.5.2 Acute and chronic effects

Pesticide exposure can produce acute and chronic effects.

6.5.2.1 Acute effects

Acute exposures and acute effects involve short-term high concentrations and produce immediate effects. Acute exposures are sudden, can be severe, and are

characterized by rapid absorption of the offending material. Acute effects can be both topical, affecting the area of the body that had direct contact with the pesticide, and systemic, affecting other parts of the body, such as the nervous system, liver, kidneys, and other organs.

6.5.2.2 Chronic effects

Chronic exposures and chronic effects involve long-term, repeated low concentrations producing latent or delayed effects. The worker may be unaware of the exposures as they occur. Chronic toxicity can be described by type of exposure (e.g., chronic dermal, chronic oral, or chronic inhalation).

6.5.3 Cholinesterase inhibition

One of the more common effects of excessive exposure to some pesticides is cholinesterase inhibition. It can be acute or chronic. Carbamate and organophosphate pesticides, such as carbaryl and malathion, destroy the cholinesterase enzyme in red blood cells. The body needs the enzyme for proper nerve function.

6.5.4 Toxicity and health hazards

The terms “toxicity” and “hazard” are often used interchangeably with pesticides, but they are not the same thing. Toxicity is the pesticide property that produces an unwanted effect when the pesticide has reached a sufficient concentration at a certain receptor site (target organ or site of action) in the body. Toxicity is determined according to an index number (e.g., grams [g]/kg body weight or parts per million [ppm]) derived from laboratory tests on animals (normally rats).

Hazard is the probability or likelihood that the concentration of the pesticide in the body will occur and produce an adverse effect. Many factors contribute to determining the degree of hazard: route of entry; dosage (concentration); physiological State; environmental variables; frequency, duration, and magnitude of exposure; the chemical formulation; and work practices, engineering, and PPE controls used.

If good work practices are followed and PPE is used, even the most toxic pesticides may be used safely without creating a health hazard. Conversely, improper handling and application of low-toxicity pesticides may result in serious injury.

6.5.4.1 Toxicity determinations

Pesticide product toxicity is determined from a variety of acute, subchronic, and chronic toxicity tests, and studies to assess carcinogenicity, mutagenicity, teratogenicity, and pesticide metabolism.

6.5.4.2 Acute studies

Acute studies provide information on health conditions likely to arise as a result of short-term exposure (hours to days).

6.5.4.3 Subchronic studies

Subchronic studies provide information on health conditions that arise from repeated exposures over a limited period of time (days to weeks). They provide information on organs and the chemical potential to accumulate in tissues. Tests are useful for establishing safety criteria for human exposure, but are insufficient for detecting effects with a long latency period, such as carcinogenicity.

6.5.4.4 Chronic studies

Chronic studies determine the effects on mammals following prolonged and repeated exposure (months to years). Health effects with a long latency period, or which are cumulative, should be detected in these tests.

6.5.4.5 Teratogenicity and reproduction studies

Teratogenicity studies determine a pesticide's potential to induce birth defects in a fetus because of the mother's exposure during pregnancy.

6.5.4.6 Mutagenicity studies

A battery of tests is made of each pesticide to assess the potential to affect the genetic material in mammalian cells. Studies include the chemical's capacity to alter cell genetic material and the relevance of such alterations to mammals. When mutagenic potential is found, these results are used to assess heritable effects, as well as oncogenic and other health effects.

6.5.4.7 Metabolism studies

Study data on the absorption, distribution, retention, metabolism, and excretion of a pesticide aid in evaluating test results from other toxicity studies. They are used to extrapolate laboratory animal test data to humans. The main purpose of metabolism studies is to understand the chemical's behavior relative to human metabolism at exposure levels of intended usages as a pesticide.

6.5.4.8 Categories of pesticide toxicity

All pesticide products are categorized on the basis of acute toxicity from Category I through Category IV. Category I pesticides are most toxic, whereas Category IV are the least toxic. To comprehend how the categories are determined, one needs to understand the criteria used in ranking acute toxicity:

- When a pesticide is applied to test animals, the dose that will kill one-half (50 percent) of the animals tested is referred to as the "lethal dose 50 percent" (LD_{50}).
- When material is tested by applying it to the skin of animals, the result is referred to as "Dermal" (LD_{50}).
- When material is fed to animals, the reference is "Oral" (LD_{50}).
- When material is mixed with air to measure the inhalation toxicity of chemicals, and the concentration of chemical kills 50 percent of the test population, the mixture is called the "lethal concentration" 50 percent (LC_{50}).
- When eye and skin irritation tests are rated by the length of time the effects last.

Each pesticide product is assigned a toxicity category, based on the highest hazard shown by any one of the indicators in Table 5.4.8. Each category is assigned a signal word, which must appear prominently on the product label. Toxicity category is one of the criteria used to determine the warnings and precautions that appear on product labels.

Table 6.5.4.8.—Criteria used in determining toxicity categories of pesticide products

Toxicity category and signal word	Hazard indicators				
	Oral LD_{50}	Inhalation LC_{50}	Dermal LD_{50}	Eye effects	Skin effects
I DANGER*	Up to and including 50 mg/kg	Up to and including 0.2 mg/L	Up to and including 200 mg/kg	Corrosive; corneal opacity not reversible within 7 days	Corrosive
II WARNING	From 50 through 500 mg/kg	From 0.2 through 2 mg/L	From 200 through 2,000 mg/kg	Corneal opacity reversible within 7 days; irritation persisting for 7 days	Severe irritation at 72 hours
III CAUTION	From 500 through 5,000 mg/kg	From 2 through 20 mg/L	From 2,000 through 20,000 mg/kg	No corneal opacity; irritation reversible within 7 days	Moderate irritation at 72 hours
IV CAUTION	Greater that 5,000 mg/kg	Greater than 20 mg/L	Greater than 20,000 mg/kg	No irritation	Mild or slight irritation at 72 hours

Note: The word "poison" and the skull and cross bones are required to be predominantly displayed on all products assigned to Category I because of oral, inhalation, or dermal criteria.

6.6 Pesticide safety training

Employee training in pesticide safety is essential and helps aid in the prevention of mishaps and accidental exposure. Environmental health and safety training are required by OSHA's Hazardous Communication Standards, DOI, and Reclamation D&S for all employees who may be exposed to potentially hazardous chemicals and materials in the workplace.

OSHA regulations (Subpart H of 29 CFR 1960) require Federal agencies to train supervisory employees in hazard anticipation, recognition, evaluation, and control procedures, and to inform them of their responsibility to provide and maintain safe working conditions through the use of engineering and administrative controls (e.g., work practices) and PPE.

The DOI's Safety and Health Manual (DM 485 DM1-7, 13-14, 17-20, and 24) mandates specialized job safety and health training that is appropriate to the work performed and specific training programs for specialized occupations (e.g., pesticide applicators). In addition, supervisors are to be trained to manage safety programs in their work units. New employees or employees new to a job assignment are required to be instructed by their immediate supervisors on proper work practices.

6.6.1 Certified applicator training

Pesticide applicator training, testing, and certification are operated by the States and through EPA-approved Federal agency programs.

6.6.1.1 Category standards

Pesticide applicator candidates must show specific knowledge about the category for which they seek certification.

6.6.1.2 Categories of certification

Applicators may be certified in 1 or more of 10 specific defined categories and related topics. Certification in one category does not permit applicators to work in another category, unless they are certified in that specific category. The categories include:

- Agricultural pest control, including control on non-crop lands
- Forest pest control
- Ornamental and turf pest control
- Seed treatment
- Aquatic pest control

- Right-of-way control
- Industrial, institutional, structural, and health-related pest control
- Public health pest control
- Regulatory pest control
- Pest control research and demonstration

The categories that are most applicable to Reclamation projects are described in more detail below:

Agricultural Pest Control requires practical knowledge of crops, rangelands, soils and water sciences, pre-harvest and reentry intervals, phytotoxicity, potential for environmental contamination, nontarget injury, and community problems resulting from the use of pesticides.

Aquatic Pest Control requires practical knowledge of aquatic pesticide application rates, formulations, water-use situations and potential downstream effects, and potential non-target effects on plants, fish, birds, beneficial insects, and other organisms present in aquatic environments

Right-of-Way Pest Control requires practical knowledge of a wide variety of environments and terrains including waterways, runoff, drift, and excessive foliage-destruction problems, the nature of herbicides and need to contain them within right-of-way areas, and awareness of the application impact upon adjacent areas and communities.

Other certification categories are described in EPA regulations 40 CFR 171.

6.6.1.3 Competency testing

Competence is determined by written examinations, including sample problem solving. The written examination may be supplemented with performance testing. The written examination covers the following topics:

- Pesticide toxicity, human hazard, and common routes of exposure
- Common types and causes of pesticide accidents
- Precautions to minimize injury to applicators and other individuals
- Personal protective clothing and equipment
- Signs and symptoms of pesticide poisoning
- Pesticide accident-response procedures
- Identification, storage, transport, handling, and mixing procedures
- Pesticide, waste, and container disposal methods
- Pest identification
- State laws and other applicable rules and regulations

6.7 Pesticide hazard communication

Specific safety-related information on pesticide products and a.i. is available from several sources. Two important sources required by Federal law and regulation (EO 12196) are the product label/labeling and the SDS. For further discussion, the term "label' includes "labeling." Legally, a label is information printed directly on, or firmly affixed to, a product container. Labeling is all other information intended to accompany the product or to which the label may refer. Both are legal documents.

When a pesticide is registered, it is often impossible to include all instructions—such as various application rates and methods—on the label itself. Other useful sources of safety information include the Current Intelligence Bulletins on specific toxic substances prepared by the National Institute for Occupational Safety and Health (NIOSH), the Agency for Toxic and Disease Service Registry, other Government agencies, and a variety of other types of technical publications.

6.7.1 Safety data sheets

The Hazard Communication Standard (HCS) (29 CFR 1910.1200(g)), revised in 2012, requires that the chemical manufacturer, distributor, or importer provide Safety Data Sheets (SDSs) (formerly MSDSs or Material Safety Data Sheets) for each hazardous chemical to downstream users to communicate information on these hazards. The information contained in the SDS is largely the same as the MSDS, except now the SDSs are required to be presented in a consistent user-friendly, 16-section format. This following provides guidance to help workers who handle hazardous chemicals to become familiar with the format and understand the contents of the SDSs.

The SDS includes information such as the properties of each chemical; the physical, health, and environmental health hazards; protective measures; and safety precautions for handling, storing, and transporting the chemical. The information contained in the SDS must be in English (although it may be in other languages as well).

Sections 1 through 8 and 10 contain general information about the chemical, identification, hazards, composition, safe handling practices, and emergency control measures (e.g., firefighting). This information should be helpful to those that need to get the information quickly. Sections 9 through 11 and 16 contain other technical and scientific information, such as physical and chemical properties, stability and reactivity information, toxicological information, exposure control information, and other information including the date of preparation or last revision. The SDS must also state that no applicable information was found when the preparer does not find relevant information for any required element.

The SDS must also contain Sections 12 through 15, to be consistent with the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS).

A description of all 16 sections of the SDS, along with their contents, is presented below:

Section 1: Identification
This section identifies the chemical on the SDS as well as the recommended uses. It also provides the essential contact information of the supplier. The required information consists of:

- Product identifier used on the label and any other common names or synonyms by which the substance is known.
- Name, address, phone number of the manufacturer, importer, or other responsible party, and emergency phone number.
- Recommended use of the chemical (e.g., a brief description of what it actually does, such as flame retardant) and any restrictions on use (including recommendations given by the supplier).

Section 2: Hazard(s) identification
This section identifies the hazards of the chemical presented on the SDS and the appropriate warning information associated with those hazards. The required information consists of:

- The hazard classification of the chemical (e.g., flammable liquid, category1).
- Signal word.
- Hazard statement(s).
- Pictograms (the pictograms or hazard symbols may be presented as graphical reproductions of the symbols in black and white or be a description of the name of the symbol (e.g., skull and crossbones, flame).
- Precautionary statement(s).
- Description of any hazards not otherwise classified.
- For a mixture that contains an ingredient(s) with unknown toxicity, a statement describing how much (percentage) of the mixture consists of ingredient(s) with unknown acute toxicity. Please note that this is a total percentage of the mixture and not tied to the individual ingredient(s).

Section 3: Composition/information on ingredients
This section identifies the ingredient(s) contained in the product indicated on the SDS, including impurities and stabilizing additives. This section includes information on substances, mixtures, and all chemicals where a trade secret is claimed. The required information consists of:

Substances
- Chemical name
- Common name and synonyms
- Chemical Abstracts Service (CAS) number and other unique identifiers
- Impurities and stabilizing additives, which are themselves classified and which contribute to the classification of the chemical

Mixtures
- Same information required for substances
- The chemical name and concentration (i.e., exact percentage) of all ingredients which are classified as health hazards and are:
    - Present above their cut-off/concentration limits or
    - Present a health risk below the cut-off/concentration limits.
- The concentration (exact percentages) of each ingredient must be specified except concentration ranges may be used in the following situations:
    - A trade secret claim is made,
    - There is batch-to-batch variation, or
    - The SDS is used for a group of substantially similar mixtures.
    - Chemicals where a trade secret is claimed
- A statement that the specific chemical identity and/or exact percentage (concentration) of composition has been withheld as a trade secret is required.

Section 4: First-aid measures
This section describes the initial care that should be given by untrained responders to an individual who has been exposed to the chemical. The required information consists of:
- Necessary first-aid instructions by relevant routes of exposure (inhalation, skin and eye contact, and ingestion).
- Description of the most important symptoms or effects, and any symptoms that are acute or delayed.
- Recommendations for immediate medical care and special treatment needed, when necessary.

Section 5: Fire-fighting measures
This section provides recommendations for fighting a fire caused by the chemical. The required information consists of:

- Recommendations of suitable extinguishing equipment, and information about extinguishing equipment that is not appropriate for a particular situation.

- Advice on specific hazards that develop from the chemical during the fire, such as any hazardous combustion products created when the chemical burns.

- Recommendations on special protective equipment or precautions for firefighters.

Section 6: Accidental release measures
This section provides recommendations on the appropriate response to spills, leaks, or releases, including containment and cleanup practices to prevent or minimize exposure to people, properties, or the environment. It may also include recommendations distinguishing between responses for large and small spills where the spill volume has a significant impact on the hazard. The required information may consist of recommendations for:

- Use of personal precautions (such as removal of ignition sources or providing sufficient ventilation) and protective equipment to prevent the contamination of skin, eyes, and clothing.

- Emergency procedures, including instructions for evacuations, consulting experts when needed, and appropriate protective clothing.

- Methods and materials used for containment (e.g., covering the drains and capping procedures).

- Cleanup procedures (e.g., appropriate techniques for neutralization, decontamination, cleaning or vacuuming; adsorbent materials; and/or equipment required for containment/clean up)

Section 7: Handling and storage
This section provides guidance on the safe handling practices and conditions for safe storage of chemicals. The required information consists of:

- Precautions for safe handling, including recommendations for handling incompatible chemicals, minimizing the release of the chemical into the environment, and providing advice on general hygiene practices (e.g., eating, drinking, and smoking in work areas is prohibited).

- Recommendations on the conditions for safe storage, including any incompatibilities. Provide advice on specific storage requirements (e.g., ventilation requirements).

Section 8: Exposure controls/personal protection
This section indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker exposure. The required information consists of:

- OSHA Permissible Exposure Limits (PELs), American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the safety data sheet, where available.

- Appropriate engineering controls (e.g., use local exhaust ventilation, or use only in an enclosed system).

- Recommendations for personal protective measures to prevent illness or injury from exposure to chemicals, such as personal protective equipment (PPE) (e.g., appropriate types of eye, face, skin or respiratory protection needed based on hazards and potential exposure).

- Any special requirements for PPE, protective clothing or respirators (e.g., type of glove material, such as polyvinyl chloride or nitrile rubber gloves; and breakthrough time of the glove material).

Section 9: Physical and chemical properties
This section identifies physical and chemical properties associated with the substance or mixture. The minimum required information consists of:

- Appearance (physical state, color, etc.);
- Upper/lower flammability or explosive limits;
- Odor;
- Vapor pressure;
- Odor threshold;
- Vapor density;
- pH;
- Relative density;
- Melting point/freezing point;
- Solubility(ies);
- Initial boiling point and boiling range;
- Flash point;

- Evaporation rate;
- Flammability (solid, gas);
- Partition coefficient: n-octanol/water;
- Auto-ignition temperature;
- Decomposition temperature; and
- Viscosity.

The SDS may not contain every item on the above list because information may not be relevant or is not available. When this occurs, a notation to that effect must be made for that chemical property. Manufacturers may also add other relevant properties, such as the dust deflagration index (Kst) for combustible dust, used to evaluate a dust's explosive potential

Section 10: Stability and reactivity
This section describes the reactivity hazards of the chemical and the chemical stability information. This section is broken into three parts: reactivity, chemical stability, and other. The required information consists of:

- Reactivity - description of the specific test data for the chemical(s). This data can be for a class or family of the chemical if such data adequately represent the anticipated hazard of the chemical(s), where available.

- Chemical stability - indication of whether the chemical is stable or unstable under normal ambient temperature and conditions while in storage and being handled.

- Description of any stabilizers that may be needed to maintain chemical stability.

- Indication of any safety issues that may arise should the product change in physical appearance.

- Indication of the possibility of hazardous reactions, including a statement whether the chemical will react or polymerize, which could release excess pressure or heat, or create other hazardous conditions. Also, a description of the conditions under which hazardous reactions may occur.

- List of all conditions that should be avoided (e.g., static discharge, shock, vibrations, or environmental conditions that may lead to hazardous conditions).

- List of all classes of incompatible materials (e.g., classes of chemicals or specific substances) with which the chemical could react to produce a hazardous situation.

- List of any known or anticipated hazardous decomposition products that could be produced because of use, storage, or heating. (Hazardous combustion products should also be included in Section 5 (Fire-Fighting Measures) of the SDS.)

Section 11: Toxicological information
This section identifies toxicological and health effects information or indicates that such data are not available. The required information consists of:

- Information on the likely routes of exposure (inhalation, ingestion, skin and eye contact). The SDS should indicate if the information is unknown.

- Description of the delayed, immediate, or chronic effects from short- and long-term exposure.

- The numerical measures of toxicity (e.g., acute toxicity estimates such as the LD50 (median lethal dose)) - the estimated amount [of a substance] expected to kill 50% of test animals in a single dose.

- Description of the symptoms. This description includes the symptoms associated with exposure to the chemical including symptoms from the lowest to the most severe exposure.

- Indication of whether the chemical is listed in the National Toxicology Program (NTP) Report on Carcinogens (latest edition) or has been found to be a potential carcinogen in the International Agency for Research on Cancer (IARC) Monographs (latest editions) or found to be a potential carcinogen by OSHA.

Section 12: Ecological information
This section provides information to evaluate the environmental impact of the chemical(s) if it were released to the environment. The information may include:

- Data from toxicity tests performed on aquatic and/or terrestrial organisms, where available (e.g., acute or chronic aquatic toxicity data for fish, algae, crustaceans, and other plants; toxicity data on birds, bees, plants).

- Whether there is a potential for the chemical to persist and degrade in the environment either through biodegradation or other processes, such as oxidation or hydrolysis.

- Results of tests of bioaccumulation potential, making reference to the octanol-water partition coefficient (K_{ow}) and the bio-concentration factor (BCF), where available.

- The potential for a substance to move from the soil to the groundwater (indicate results from adsorption studies or leaching studies).

- Other adverse effects (e.g., environmental fate, ozone layer depletion potential, photochemical ozone creation potential, endocrine disrupting potential, and/or global warming potential).

Section 13: Disposal considerations
This section provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices. To minimize exposure, this section should also refer the reader to Section 8 (Exposure Controls/Personal Protection) of the SDS. The information may include:

- Description of appropriate disposal containers to use.
- Recommendations of appropriate disposal methods to employ.
- Description of the physical and chemical properties that may affect disposal activities.
- Language discouraging sewage disposal.
- Any special precautions for landfills or incineration activities

Section 14: Transport information
This section provides guidance on classification information for shipping and transporting of hazardous chemical(s) by road, air, rail, or sea. The information may include:

- UN number (i.e., four-figure identification number of the substance).
- UN proper shipping name.
- Transport hazard class(es).
- Packing group number, if applicable, based on the degree of hazard.
- Environmental hazards (e.g., identify if it is a marine pollutant according to the International Maritime Dangerous Goods Code (IMDG Code)).
- Guidance on transport in bulk (according to Annex II of MARPOL 73/783 and the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (International Bulk Chemical Code (IBC Code)).
- Any special precautions which an employee should be aware of or needs to comply with, in connection with transport or conveyance either within or outside their premises (indicate when information is not available).

Section 15: Regulatory information
This section identifies the safety, health, and environmental regulations specific for the product that is not indicated anywhere else on the SDS. The information may include:

- Any national and/or regional regulatory information of the chemical or mixtures (including any OSHA, Department of Transportation, Environmental Protection Agency, or Consumer Product Safety Commission regulations).

Section 16: Other Information
This section indicates when the SDS was prepared or when the last known revision was made. The SDS may also state where the changes have been made to the previous version. You may wish to contact the supplier for an explanation of the changes. Other useful information also may be included here.

6.7.2 Pesticide labeling

Before pesticides can be registered, the manufacturer or formulator must meet two critical information requirements. Under provisions of the EPA regulations: (1) the product label must contain specified application, chemical, and safety information; (2) product labels must be submitted for approval to EPA before the product can be sold.

The pesticide product information on the label is critical. The label is a legal document and must be followed when using the product. Using a pesticide in a manner that is inconsistent with labeled instructions can result in both civil and criminal penalties.

Information is put on the label to protect both people and the environment; it is important that it be read and understood. Pesticide labels conform to Federal standards, and each is required to have the following specific information:

6.7.2.1 Brand name or trademark

The brand name, which is used to market the product, usually is the largest and most conspicuous wording on the label. Customarily, the name is a registered trade mark.

6.7.2.2 Ingredients statement

All active or toxic ingredients in a pesticide product must be printed on the label as percentages by weight. Most pesticides have official common names; the common name, if there is one, is required on the label. The common name is

followed by the chemical name of the ingredient. The chemical name is required on the label unless the common name is well known. Some products have two or more a.i..

Labeled statements sometimes show the ingredient percentage (and with liquids, the pounds per gallon) of the technical form of the chemical to which the amount of a.i. is equal. Inert ingredients are not required to be listed by chemical name, but the label must show what percentage of the total material is inert.

6.7.2.3 Net contents

The label must specify how much material is in the container, usually by weight if it is dry material or by volume if it is liquid. Some labels maybe marked “Bulk (Xylene)” when shipped in bulk (tanker) quantities.

6.7.2.4 Manufacturer's name and address

Each pesticide label must include the name of the company that manufactured or formulated the product. If two or more companies are involved, the label must specify all names and addresses.

6.7.2.5 Product registration and establishment numbers

The registration number on the label indicates that the product has been registered with the EPA (or qualified State agency). The establishment number identifies the final facility where the pesticide was made, formulated, or packaged.

6.7.2.6 Statement-of-use classification

The statement "Restricted Use Pesticide" is required whenever labels provide directions for uses classified as restricted. The statement must appear in large type at the top of the front label.

6.7.2.7 Human hazard signal words and symbols

The hazard to humans is indicated on the product label by the signal words shown in table 7.3. In addition, if the product is assigned to Toxicity Category I because of oral, inhalation, or dermal toxicity, the words DANGER—POISON must be shown, with skull and crossbones on a background of contrasting color. All labels must bear the statement, "Keep out of reach of children," on the front label, in addition to other signal words and symbols.

6.7.2.8 Warnings and precautionary statements

The label contains warnings and precautionary statements setting forth other hazards to humans, domestic animals, and the environment, and physical and chemical hazards associated with product use. For example, the label may indicate that the product poses a special danger if inhaled or that the product is highly combustible. Usually, this statement will indicate required precautions against the special dangers, such as directing the applicator to use an approved respirator or other necessary PPE, or mix the product only in fire-safe locations.

6.7.2.9 Statement of practical treatment

The label states which first aid measures to use if a person is accidentally exposed to pesticide. The label will indicate when to seek medical attention for exposure and may provide more specific instructions for medical personnel.

6.7.2.10 Directions for use

Directions for pesticide use contain information and instructions about:

- Areas or objects to be treated
- Target pest
- Application rate for each area or pest
- Method of application, including instructions for dilution, and protective devices required
- Frequency and timing of applications to obtain effective results without causing adverse effects on the environment
- Special limitations on re-entry to treated areas
- Restrictions on use to prevent unreasonable adverse effects, such as required intervals between application and crop harvest for food or feed
- Crop rotation restrictions
- Warnings against use on certain crops, animals, objects, or in certain areas
- Other pertinent information necessary to protect people and the environment

6.7.2.11 Storage and disposal

The label or the SDS will give specific directions concerning storage and disposal of the pesticide and container. Some directions for use may be contained in labeling information; if they are, the label must refer to them. Disposal of pesticides and container shall be in accordance with Federal, State and Local environmental regulations.

6.7.2.12 Misuse statement

The label prohibits use of the pesticide in any manner inconsistent with the label. Such use can be dangerous, as well as a FIFRA violation.

6.7.2.13 Other references

EPA, NIOSH and OSHA have compiled summary safety-related information and data for many hazardous chemicals, including some of the more commonly used pesticides such as carbaryl, malathion, and 2,4-D. These data have been published in the form of Occupational Safety and Health Guidelines bulletins. Each bulletin is devoted to specific material or materials. A three-volume publication, Occupational Guidelines for Chemical Hazards, 1981 (PB-83-154- 609), containing all guideline bulletins and current updates, is available by contacting the National Technical Information Service (NTIS) in Springfield, Virginia (703) 605-6060, or accessing the NTIS Web site: www.ntis.gov/.

Another good source of technical information on pesticides is Criteria Documents, published by NIOSH; each document is devoted to a specific material and covers other substances in addition to pesticides. A list of documents can be obtained by calling the NIOSH Publications Office at 1-800-356-4674 or 513-533-8328. The publications are also available from NTIS or by contacting NIOSH at www.cdc.gov/niosh/.

A number of other sources of technical information on pesticides and pesticide safety are available. They include manufacturers' technical bulletins for specific products and various monographs, trade and technical publications, and textbooks (See bibliography). In addition, pesticide experts at land-grant colleges or the State's Cooperative Extension Service can provide valuable information on State and local pesticide laws and regulations, as well as serve as sources of current pesticide research and practical information.

6.8 Handling and applying pesticides

The most frequent pesticide accidents are spills and leaking containers. The most important activity in managing these problems is prevention. Preventing accidents and human exposures is accomplished by proper storage, transportation, and

handling practices. Safety is enhanced through frequent inspection of storage facilities, pesticide containers, and mixing and loading sites; the wearing of chemical protective clothing and devices; and the training of workers.

6.8.1 Storing pesticides

Limit the quantity of pesticides in storage. Stockpiling should be discouraged and minimized. The label and SDS will give storage directions for pesticides that require special attention or conditions. Pesticides should be stored in a secure, well-ventilated area and be segregated according to compatibility. The storage area must be properly placarded with warning signs and the National Fire Protection Association (NFPA) 704 fire diamond. Storage requirements will be prescribed by State or local fire regulations. Under SARA Title III, Public-Right-to-Know, stored quantities of certain chemicals must be reported to the local state and Federal agencies. Some municipalities may have adopted the NFPA's model code for pesticide storage.

Key points in pesticide storage include:

- Protect stored pesticides from rain
- Protect chemicals from freezing temperatures and direct sun
- Post emergency telephone numbers near appropriate telephones within the facility and at a convenient distance from the facility
- Equip and maintain an emergency "spill kit" that will be readily accessible if a spill or fire occurs
- Implement ventilation recommendations
- Prepare evacuation plan
- Prepare spill response plan

6.8.1.1 Storage facilities

Store pesticides in a separate, dry, well-ventilated, and a well-illuminated building. Provide a separate ventilation system for the mixing and storage areas of the pesticide storage facility. Ventilation systems that provide a minimum of six air changes per hour are usually required. Stored pesticides shall be segregated according to compatibility. Upon selecting a site or constructing a storage building, the area should have good drainage away from the building to minimize runoff to public and other sensitive areas. Requirements for the design and construction of a pesticide storage facility are extensive. Many States have specific designs and requirements for pesticide storage facilities. Check with State

authorities for specific requirements. For additional information, the U.S. Department of Defense has issued Technical Guide 17, “Military Handbook, Design of Pest Management Facilities”, which is available at the following web site: www.acq.osd.mil/eie/afpmb/techguides.html.

When a separate building cannot be used, choose a wing or corner, preferably on the first floor (never a basement), with outside access to facilitate evacuation and fire protection. Install an approved fire suppression system.

Mark each outside building wall with legible, prominent, permanent, black-and-white signs that display the word PESTICIDES in bold capital letters at least 2 inches high. When Category I pesticides are stored in the building, add the words DANGER and POISON, and a skull and crossbones symbol to the signs. Windows should be barred. Lock the building when unoccupied and prohibit loitering in or near it. Mark the outside of the building with a NFPA 704 fire diamond.

An emergency eyewash and shower must be located in, or immediately adjacent to, the pesticide storage facility for emergencies that require washing of eyes, and body parts.

6.8.1.2 Storage management

Inspect the facility weekly for unsafe conditions. Maintain an accurate current inventory of all chemical and pesticide products.

6.8.1.3 Aisles

Keep the aisles between pesticide stacks clear; make sure they are wide enough to allow access with hand-held firefighting equipment. Conduct visual inspections for leaks, corrosion, and other signs of package deterioration. Shelving systems should be constructed of plastic or metal. Avoid wood shelves or pallets because wood will absorb chemicals and become contaminated.

6.8.1.4 Labels

Ensure that each side of each stack of pesticides has a visible label so the contents of the stack can be identified when approached from all directions.

6.8.1.5 Containers

Store pesticides only in their original, tightly sealed containers. Make sure labels are clearly visible. Periodically check containers for leaks, corrosion, and other signs of deterioration. Containers shall remain closed when not in use.

6.8.1.6 Chemical inventory and SDS

Keep up-to-date SDSs for all stored pesticides, along with an inventory showing amounts of each pesticide. Maintain current SDSs at the storage location. The SDSs should be maintained in a loose-leaf binder, in alphabetical order. It is a good idea to maintain an additional copy at another location in case of an emergency.

6.8.1.7 Damp floors

Concrete floors in most parts of the country condense moisture. Do not store pesticides on damp floors; store them on plastic or metal pallets. The floor should be constructed to be impervious to liquids. Concrete floors that have not been treated with a sealant will absorb moisture or liquid spills. Pesticide containers, where practical, should have secondary storage to control and contain spills.

6.8.1.8 Fertilizers

Do not store fertilizers, particularly ammonium nitrate, in the same building with pesticides. Chemical compatibility of chemicals stored with pesticides must be carefully considered. Review the SDS or contact a health and safety professional or the fire department for further information.

6.8.1.9 Other items

Do not store decontamination and cleaning supplies, food, animal feed, or seed in the building.

6.8.1.10 Notification

Personally inform the local fire and police departments of the layout and current contents of the storage facility. Provide the fire department with current chemical inventory with quantities and the product SDS. Depending on the type and quantity of the pesticide, official reporting outlined under Superfund Amendments and Reauthorization Act (SARA) Title III may be required. Be sure to provide the emergency responders with a 24-hour telephone contact person. Inform local hospitals and the regional poison control center of chemical and pesticide products stored at your facility. Reclamation Regional or Area Offices Hazmat Coordinators shall be contacted to help with reporting to regulatory agencies.

6.8.1.11 Leaking containers

Weekly inspections of storage facilities may reveal leaking or damaged containers. Separate clean, undamaged containers from those that are leaking. Follow precautions cited for spills on the labels.

Containers that have been contaminated should be isolated for cleaning. If practical, repackage the material. For leaking containers of liquids, repackage the pesticides in new containers of the same type used originally. Insert broken bags of dry material into heavy-duty plastic bags and seal with twist ties. Label the repackaged pesticides with exact duplicates of the original labels; note the repackaging date on the outside of the new container. Use repackaged pesticides before using those in the original containers.

When repackaging a pesticide, work only in a well ventilated area. Be sure to follow label or SDS requirements for PPE required for handling, mixing, and loading. Transfer contents of the leaking container by elevating it and pouring or siphoning the contents into the new container. Use a forklift to lift large containers. When pouring, use a wide-mouth funnel to reduce slopping and splashing. If you siphon, use a mechanical pump or siphon. Never start a siphon by mouth.

6.8.2 Transporting pesticides

Pesticides can present a hazard when they are involved in an accident during transportation. Pesticide containers can rupture, releasing product to the environment, air, ground, and water. Combustible pesticide products can release combustion products to the atmosphere and can potentially impact susceptible populations distant from the accident. Meteorological conditions can spread toxic chemicals over large areas. The motor vehicle operator must be trained to take appropriate spill countermeasures to preclude the release and spread of pesticide product to the air, ground, and water in accordance with OSHA's Hazardous Waste Operations and Emergency Response (HAZWOPER) regulations. In the event of a mishap, the motor vehicle operator must secure the area and then notify the appropriate authorities and the Regional or Area Office Hazmat Coordinators.

6.8.2.1 Material classes for transportation

When pesticides are transported on public highways, DOT hazardous material regulations and training apply. The regulations (49 CFR 100-199) also require vehicles used for transporting chemicals to have prescribed markings and to carry certain documents related to the cargo. Vehicles transporting pesticides that meet DOT hazardous material classes must be marked with placards and a number that identifies the class of cargo. Some States have requirements that exceed DOT requirements; State highway or police departments should be consulted for specific marking requirements. The more important hazardous material classes that cover pesticides used on Reclamation projects are shown in table 8.2.1.

Table 6.8.2.1.—Important hazardous material classes for pesticides

Class 3	Flammable Liquid. Any liquid having a flash point less than 60 °C (140 °F).
Class 4.1	Flammable Solid. Any solid material, other than an explosive, that is liable to cause fire through friction or retained heat; ignites readily and burns persistently; is spontaneously combustible; or ignites in reaction to water.
Class 5.1	Oxidizer. Any substance, such as a chlorate or nitrate, that yields oxygen readily, thereby accelerating the combustion of organic matter.
Class 6.1	Poison, A. Extremely poisonous gases or liquids that, when a minuscule amount is mixed with air, become dangerous to life. Poison, B. Liquids, pastes, semisolids, and solids that are presumed to be toxic enough to be hazardous to human health. Generally, they are less hazardous than Poison A chemicals. Poison Inhalation. Acrolein, a pesticide often used in aquatic weed control, is included in this class. Irritating Material. A liquid or solid substance that, upon contact with fire or air, emits dangerous or intensely irritating fumes.

6.8.2.2 General transportation safety precautions

Each vehicle used to transport pesticides should contain a first aid kit and an appropriate spill kit. Vehicle drivers should be trained to use the spill kit. The person transporting the pesticide is legally responsible for its safe movement. The following precautions will help prevent accidents.

- Do not transport pesticides in the passenger compartment of a vehicle. The safest way to move pesticides is in the truck cargo compartment.
- Do not allow anyone to ride in the back of the truck with pesticides. A spill could cause injury.
- Do not put food, drink, or clothing in the same compartment with the pesticide.
- Tie down all containers to prevent breakage and spillage. Keep paper and cardboard containers dry.
- Do not leave unlocked pesticides unattended.
- If a pesticide is spilled in or on the truck, clean it up at once.
- If a pesticide is spilled from the truck, take precautions to contain the material, secure the area, and contact the appropriate authorities.

6.8.3 Mixing and loading pesticides

The following rules provide prudent guidelines for the handling, mixing, and loading of pesticides.

- Read the JHA; wear the proper PPE (e.g., chemical protective clothing, gloves, safety glasses, splash goggles, and/or face shield, and where indicated, a respirator). Check the operation of safety devices frequently.
- Read safety and mixing information on the product SDS and label. Make sure equipment required for a safe operation is available and functional. Contact the pest control supervisor or the health and safety professional if questions arise.
- Use DOT Segregation of Hazardous Materials Table found at 49 CFR 177.848
- Keep first aid kit, spill kit, and clean water readily available at the work area. First aid kits must be appropriate for the pesticides encountered.
- Mix the pesticides outdoors in good ventilation and light.
- When mixing pesticides, measure carefully. Use only the amount called for on the label and only the amount needed to do the job.
- Never work alone; observe partner for symptoms of exposure.
- Do not contaminate yourself; stand upwind of the pesticide mixing operation.
- Keep nonessential personnel away from the mixing and loading site.
- Use a sharp knife to open paper bags; if you tear them, pesticide is likely to spill.
- When pouring concentrated material, keep the container below shoulder level to minimize the possibility of splashing the chemical onto your face.
- Replace caps on containers; make sure they are closed when you are finished measuring out the correct amount.
- Keep stirring paddles, measuring cans, and other mixing equipment clean and stored under lock and key when not in use.
- Do not leave chemicals and mixing gear unguarded or insecurely stored if operations are temporarily discontinued.

- At day's end or project completion, whichever occurs first, return all unused chemicals and empty containers to locked storage if they cannot be immediately disposed of.
- Do not drink, eat, chew, or smoke when working around pesticides.
- If concentrated pesticide is splashed upon you:
- Stop whatever you are doing immediately.
- Remove your contaminated clothing.
- Wash your skin thoroughly with detergent and water: put on clean protective clothing.
- Secure the area.
- Clean up any spill.

6.8.4 Application equipment

Selecting application equipment for a specific job will depend on many particulars (i.e., the area to be treated, the area's location and access, pests to be controlled, and equipment available). Application equipment can be either unpowered or powered. Details of equipment for treating land and water weeds, including design specifications, can be found in the Reclamation publication, Water Operation and Maintenance Bulletin No. 97.

6.8.4.1 Manual applicators

Unpowered applicators consist of small metal or plastic containers. When pesticide is a spray, it is usually added to the container and diluted with water, and the unit is pressurized by hand-pumped air. Some units are carried by a handle with one hand, while the spray is applied with a triggered wand with the other. Other units are backpack models. Hand-pressurized applicators are usually used to apply pesticides inside buildings, such as warehouses and storerooms, and other areas where powered units would be too large or cumbersome. For minor infestations, a hand applicator is more practical and efficient.

6.8.4.2 Power applicators

Power applicators are used for rapid application of large pesticide volumes. Using power equipment, a pesticide can be sprayed over many acres in a day's time. With most power sprayers, the concentrate is mixed with a solvent, usually water, and pumped from a storage tank through distribution lines to one or more nozzles that control the size and distribution of the spray droplets. There are many kinds

of power applicators including: fogger generators, aerosol generators, dusters, granule spreaders, air-blast sprayers, low-pressure boom sprayers, ultra-low-volume sprayers, low-volume air sprayers, and high-pressure sprayers. Depending on the equipment used, they may be mounted on trucks, tractors, trailers, boats, aircraft, or carried by the applicator on their back (e.g., smaller units, similar in size to a leaf blower, are designed to be carried by applicators on their back).

6.8.4.2.1 Foggers and aerosol generators

The generators break pesticide formulations into fog-like droplets. The fog is created by atomizing nozzles, spinning disks, or heated elements called thermal generators. Their main safety problem is that even light wind can cause long-distance drift and unwanted contamination.

6.8.4.2.2 Dusters

The duster blows fine pesticide particles of dust onto the target. However, like aerosol sprays, dusts are subject to drift.

6.8.4.2.3 Granule applicators

These devices are designed to apply coarse, dry particles, usually to the soil. Granular applicators offer no special safety hazards.

6.8.4.2.4 Air blast sprayers

These units use a high-speed, fan-driven air stream to dispense the spray. A series of nozzles inject spray into the air stream, which breaks up and blows the droplets. The sprayers deliver either high or low volumes of spray. They also pose a drift hazard.

6.8.4.2.5 Low-pressure boom sprayers

Usually, these sprayers are mounted on tractors, trucks, or trailers. They are designed to deliver 20 to 60 gal per acre of pesticide at 10 to 40 pounds per square inch pressure.

6.8.4.2.6 Ultra-low-volume sprayers

These sprayers apply the chemical concentrate without diluting. Safety disadvantages include increased risk to the applicator and crew from handling and spraying concentrated material.

6.8.4.2.7 High-pressure sprayers

These sprayers deliver various volumes of spray at pressures up to several hundred pounds per square inch. While high- pressure sprayers afford greater reach than low-pressure units, the spray tends to form small droplets and drift, thus creating a potential safety hazard.

6.8.4.2.8 Low-volume air sprayers

The low-volume sprayers, often called misters or mist blowers, operate similarly to air-blast sprayers, except they use lower spray volumes. Some backpack spray units have a low-pressure metering device that injects spray material into high-speed air that atomizes the liquid.

6.8.4.2.9 Components of power application equipment

The major features of power application equipment include agitators, nozzles, pumps, and tanks.

Agitators. Without agitation, some pesticide formulations (DF, WP) will settle in the spray tank, clog lines, and change the concentration of chemical in the spray. In hydraulic agitation, some solution is reticulated through the tank. In mechanical agitation, a paddle or propeller suspended in the spray tank stirs the solution.

Nozzles control the rate, size, and uniformity of pesticide droplets during application. Optimum nozzle performance is crucial to safety. They must be cleaned, replaced when worn, and properly adjusted so pesticides are placed where (and only where) intended.

Pumps. Many types of pumps are found on application equipment. Generally, there are two safety considerations regarding them. First, the pump must produce the correct operating pressure and volume for the particular application; second, the pump—and especially its nonmetal parts, such as gaskets— must withstand the chemical action of the pesticide without excessive corrosion or leakage.

Tanks hold the pesticide and diluting liquid, and are often:

- Constructed with an agitator to keep insoluble formulations, such as WPs, in suspension
- Made of corrosion and rust-resistant materials
- Constructed with large openings for easy filling and cleaning
- Fabricated with an accurate sight gauge for determining the liquid level
- Enclosed by a spill-proof cover
- Emptied completely using a bottom drain

6.8.5 Equipment checkout and calibration

To prevent chemical contamination, routinely check application equipment for: leaks, especially in hoses and hose connections; plugged, worn, or dripping nozzles; and defective gauges, pressure regulators, and valves.
New equipment can contain foreign objects, such as metal chips, from the manufacturing process. Sprayers that have been idle for a time may contain bits of rust or other material. Failure to thoroughly clean such equipment may result in improper operation, which increases the likelihood for pesticide exposure.

6.8.5.1 Equipment calibration

Calibrate application equipment frequently so proper amounts of pesticide material are applied. Calibration also provides a final operational check on all equipment systems.

Directions for calibrating equipment are usually included in the manufacturer's operating and maintenance instructions.

6.9 General safety procedures

Most pesticide applications take several hours or longer to complete, during which time workers are continuously at risk of exposure to pesticide sprays, mists, and vapors. General procedures for minimizing these exposures are:

- Make sure the application equipment is in good operating condition and has been properly calibrated.
- Do not apply pesticides that will drift when the weather is windy or unsettled.
- Read the JHA; wear the proper PPE. Check the operation of safety devices.
- Read safety and application information on the product SDS and label. Make sure safety equipment required by the safety plan conforms with SDS and label requirements. If it does not, contact the Reclamation pest control supervisor or safety officer.
- Keep first aid kit, spill kit, and clean water readily available at or near the treatment area.
- Never work alone; observe partner for symptoms of exposure.
- Do not contaminate yourself or your partner. In a light breeze, apply pesticide from the upwind side of the treatment area.

- Do not leave equipment unattended. If equipment must be abandoned in an emergency, secure it as well as possible.

- When wearing a respirator, monitor for pesticide odors. If odors are detected, leave the environment at once; change respirator cartridges or canister, or entire respirator, before returning.

- Take rest breaks; do not eat, drink, chew, or smoke when handling pesticide products.

6.9.1 Monitoring workers

Everyone working with pesticides should be checked for signs of pesticide poisoning. Look for symptoms of poisoning at regular intervals during the day; the sooner symptoms are detected, the less likely a serious incident will result.

6.9.2 Personal protective equipment

Wearing appropriate PPE is the most practical and effective way of avoiding exposure to pesticides. However, PPE does not substitute for other essential safety practices.

Note that PPE requirements for specific pesticide applications will be found on the label or the product SDS. Requirements often vary according to the hazard that individual application tasks present to workers. Consideration of the proper PPE is an important aspect in developing the JHA.

As a minimum, persons handling pesticides should wear coveralls with hood or spray suits over long sleeve shirts; full-length pants; chemical protective rubber boots; chemical protective gloves; and splash goggles, safety glasses, and face shields (when additional face protection is necessary). Items of *personal* apparel that should not be worn include sweatbands, bandanas, or any article of leather, like wristwatch straps and belts. They will absorb pesticides; and leather items cannot be decontaminated.

6.9.2.1 Chemical protective clothing

Skin contamination can cause pesticide illness. Personal protective equipment (e.g., coveralls, aprons, spray suits, gloves, hats, and boots) is designed to protect pesticide handlers and applicators from getting pesticide on their skin. Personal protective equipment should be clean and free of defects or damage.

6.9.2.2 Coveralls

There are two types of coveralls: reusable and disposable. Reusable coveralls are made of washable fabric and may be worn several times. Disposable coveralls are lightweight and reasonably comfortable in hot weather; they offer some degree of skin protection, provided the material does not become saturated or damaged by cuts or abrasion. Disposal coveralls can be treated with a coating that makes the material more resistant to liquid penetration (e.g., Saranex®, which is Tyvek® coated with an impermeable film).

The choice between reusable and disposable coveralls should be made based on the difficulty involved in decontaminating reusable clothing from exposure to the particular pesticide product.

6.9.2.3 Aprons

Normally, coveralls provide adequate protection after the pesticide has been diluted and loaded. Persons handling concentrated pesticides need to wear an appropriate chemical protective glove or clothing (e.g., butyl, nitrile, or neoprene rubber or synthetic liquid-proof apron), especially during loading operations. Aprons must be of material that resists both the solvents used in formulating pesticides and the a.i. of the product. Aprons must cover workers, from chest to boots, to protect them from splashes.

6.9.2.4 Spray suits

When highly toxic pesticides are applied, the SDS or label may require workers to wear liquid-proof clothing that completely covers their clothes, such as rain suits. Acceptable spray suits are made of tear-resistant, heat-sealed vinyl.
The jacket has a hood (with drawstring) and covered snap closures down the front and at the wrists. The trousers have a drawstring waist and snap closures at the ankles. Full-body chemical protective clothing and warm ambient conditions can lead to heat stress. Elevated relative humidity, coupled with warm ambient air temperatures, can compound heat stress. To minimize the likelihood of developing heat stress, pesticides should be applied early in the day when ambient air temperatures are lower.

6.9.2.5 Chemical protective gloves

Pesticides and solvents are readily absorbed through the hands; protect them with chemical protective gloves. Use chemical protective gloves made of materials appropriate for the chemical product to be handled. Do not use chemical protective gloves with cloth linings or wrist bands, or leather gloves; these materials soak up pesticides and are virtually impossible to clean and make the gloves a likely source of chronic exposure.

There are a variety of gloves that can be worn when handling pesticide products. Three common chemical protective glove materials are butyl, nitrile, and neoprene rubber. Wear coverall or spray-suit sleeves outside chemical protective gloves. This prevents splashes from running inside and onto the hands.

6.9.2.6 Chemical protective head coverings

Wear a liquid-proof, washable head cover. Either a metal or plastic hat is acceptable. The hat must have a disposable sweatband that can be discarded after use or a plastic sweatband that can be washed. The American National Standards Institute (ANSI) has developed a standard for hard hats (ANSI Z89.1) that is recommended for construction personnel and should be followed by pesticide workers. Ordinary felt, straw, or cloth hats with sweatbands can absorb chemicals and cause acute, subacute, and perhaps chronic exposures.

6.9.2.7 Chemical protective boots

Do not wear leather or fabric boots; they absorb pesticides and cannot be cleaned. Liquid-proof, unlined neoprene (butyl or nitrile rubber, if available) boots must be worn when loading, mixing, or spraying pesticides. Boots should cover the area below the knee.

Wear coverall or spray-suit legs outside boots. This reduces the chance of splashes running onto legs and feet.

6.9.2.8 Chemical protective clothing care

Wear clean clothing daily. If clothes get wet with diluted pesticides, change them immediately. Launder them three times with soap and hot water or other recommended decontamination solution. Then "launder" the empty washing machine with soap and hot water.
If clothing gets wet with pesticide concentrates or highly toxic pesticides, normal washing methods will not get them clean. Dispose of clothing according to guidelines for disposing of pesticide wastes.

6.9.2.9 Face protection

6.9.2.9.1 Splash goggles

Splash goggles are effective, particularly when handling dusts, WPs, or granules. Many splash goggles will fit over ordinary eyeglasses; goggles with prescription lenses are also available. Some goggles have sweatbands of absorbent material. Avoid absorbent sweatbands or replace with nonabsorbent bands. When handling liquids, full-face protection must be worn.

6.9.2.9.2 Face shields

Goggles offer eye protection, but full-face protection is preferred when handling liquid material. Splashes are common during handling, mixing, and loading of these materials; it is important to protect the face, especially mouth and eyes. The best face shields are made of clear plastic; they attach to hard hats and are hinged so they can be raised or lowered. Face shields should be used in combination with splash goggles.

6.9.2.9.3 Care of splash goggles and face shields

Goggles and face shields need the same care as other PPE articles. Wash carefully and thoroughly after each use; carefully prevent scratches that might restrict vision.

6.9.2.10 Respiratory protection

There are two primary types of respiratory protection equipment: (1) equipment that purifies or filters the breathing air and (2) equipment that supplies clean breathing air to the worker.

6.9.2.10.1 Air purifying or filtering respirators

Air purifying or filtering respirators are appropriate for most pesticide handling activities. Chemical cartridge respirators and canister-type gas masks are the two types of air purifying respirators in general use. The cartridges and canister can be changed; specific cartridges and canisters protect against specific chemical particulates, gases, and vapors. The JHA, product label, or SDS will specify which cartridge or canister to use for the particular pesticide. Use only devices approved by NIOSH. Respirators should not be used until workers have been medically cleared, the hazard has been properly evaluated by a competent health and safety professional, workers have been properly trained, and a “fit test” has been conducted.

If respirators are required to be used when applying pesticides the pesticide applicator shall be on a medical monitoring program and have had annual respirator fit testing and training for the respirators they use.

6.9.2.10.2 Chemical cartridge respirators

Negative pressure, air purifying respirators equipped with chemical cartridges can be either a half-face, full-face, or a modified full-face respirator equipped with a battery-power supply, referred to as a powered air purifying respirator. The differences between the three respirators are the protection factor and the degree of any additional face protection.

Appropriate chemical cartridge use for the type of pesticide application is important. Cartridges contain absorbing material, (usually activated charcoal) and a prefilter pad to remove dust and spray particles. Effective cartridge life varies

according to a number of factors, (i.e., concentration of pesticide, humidity and temperature of the air, and breathing volume of the wearer). The cartridge type should be compatible with the product used. Chemical cartridges gradually lose effectiveness during storage.

6.9.2.10.3 Gas masks

Gas masks, or canister-type respirators, cover eyes, nose, and mouth. The gas mask face piece may include a canister of filtering material, or it may be connected by a flexible hose to a canister worn on the belt.

6.9.2.10.4 Supplied-air respirators

There are two types of supplied-air respirators: (1) self-contained breathing apparatus (SCBA) respirators or (2) airline respirators. Both offer excellent protection when the environmental conditions are properly evaluated by a qualified health and safety professional. Both types of supplied-air respirators have advantages and disadvantages to their use.

6.9.2.10.5 Self-contained breathing apparatus

A SCBA must be worn when working with highly concentrated toxic chemicals. Rather than furnish air from the surrounding environment, SCBAs are equipped with cylinders of compressed air, which applicators carry on their backs, like scuba-diving tanks. SCBA equipment is appropriate when applicators must apply toxic gases in enclosed spaces and in emergency situations, such as combating fires and cleaning up indoor spills. The device contains enough air to sustain an average person for 20 to 50 minutes.

6.9.2.10.6 Air line supplied air respirators

Air line devices may completely cover head and shoulders or cover only the face. An external air compressor supplies filtered air to the hood or mask.

6.9.2.10.7 Use of respiratory protection equipment

When the JHA indicates, workers must wear specified respiratory protection equipment. The respirator must snugly fit the face. Long sideburns, a beard, or eyeglasses may prevent a good seal.

Proper selection and fit will prevent most potential problems with respiratory protection equipment. Some respiratory protection equipment allows mounting of corrective lenses to inside face pieces. If a worker must wear corrective lenses mounted in the face piece, be sure the lenses are fitted by a qualified person to maintain vision, comfort, and a gas-tight facial seal.

When an operator can smell odors, there is either an equipment leak or the respirator is not properly fitted to the face. If a person wearing a negative pressure, air purifying respirator equipped with chemical cartridges experiences increased breathing resistance, or tastes or smells the chemical contaminant, he or she must leave the environment at once and change filters and cartridges, or canisters, before reentry. Not all chemical contaminants will have an odor or taste. Therefore, odor and taste cannot be relied on as a means of determining when a chemical cartridge has exceeded its service life.

6.9.2.11 Maintenance and care of respirators

Respiratory protection is no better than the respirator in use. A qualified respiratory protection program manager or a health and safety professional must frequently inspect all respiratory protection equipment used in pesticide operations to ensure they are maintained at their level of original effectiveness. The only certain way for maintaining efficiency is to establish a routine maintenance program.

On a regular schedule, and before and after each use, inspect equipment for defects and leaks. Respirators must be kept clean, disinfected, and properly stored between uses.

6.9.2.11.1 Defects and leaks

Check tightness of connections and condition of face mask, headbands, valves, connecting tube, canisters, cartridges, or air tanks. Elastic parts should be checked for pliability and signs of deterioration.

6.9.2.11.2 Cleaning and disinfecting

Clean and disinfect respirators after each use. Follow manufacturer's directions. Remove and discard filters, cartridges, and canisters. Wash face pieces with detergent and water, rinse, and dry with a clean cloth.

6.9.2.11.3 Repairs

Allow only experienced, trained technicians to repair respirators. Replace parts only with those designed for the particular make and model of the device. Adhere strictly to manufacturer's specifications. Return all valves and regulators to the manufacturer, or service center, for adjustment or repair.

6.9.2.11.4 Storage

After inspection, cleaning, and repair, store respirators to protect them from dust, sunlight, heat, freezing, and excessive moisture. Store away from pesticides and other chemicals. Make sure the face mask and exhalation valves are in a normal position. Follow manufacturer's storage recommendations.

6.9.2.11.5 Air supply

At least monthly, and before use, inspect the SCBA. Ensure that the air cylinders are fully charged in accordance with the manufacturer's specifications and that the regulators and warning devices function properly.

6.9.2.11.6 Emergency-use respirator

Respirators for emergencies should be accessible at all times. Clearly mark emergency storage cabinets. Keep respirators inside easily identified cases.

6.9.2.11.7 Maintenance records

Maintain records of inspection dates, findings, repairs made, parts replaced, and air cylinders recharged.

6.10 Job hazard analysis

The JHA is a process for anticipating, recognizing, evaluating, and controlling potentially unsafe acts and conditions associated with each step of a job. The JHA should provide sufficient detail to convey all essential and pertinent information to those involved in the pesticide project. Information in the JHA should be verified and validated to avoid unnecessary confusion and delay in the event of an emergency. The JHA template can be used in its entirety or adapted for your project.

6.10.1 JHA pesticide requirements

A JHA shall be completed for all pesticide jobs that are performed by Reclamation employees. The term "pesticide job" refers to the definite sequence of activities required to complete a work goal. It involves the use of a specific pesticide in a particular place with specific equipment. In addition to *pesticide use or application,* the definition also covers jobs involving the *handling* of pesticides; for example, the transporting, storing, moving, repackaging, or disposing of pesticides or pesticide containers.

6.10.2 Personnel involved

Pesticide jobs should be reviewed and evaluated by the staff in Reclamation project or operation and maintenance offices that are responsible for the work and are thoroughly familiar with the local conditions. A JHA is most effective when completed as a team effort and when the team includes a lead reviewer (the responsible foreman, Pest Control Supervisor, or Pest Management Specialist) and one or more of the employees who normally perform the job. At least one person on the team should be a Certified Applicator.

The review process is a convenient way to keep managers and health and safety professionals informed about the scope of pesticide jobs and the need for special safety equipment and procedures.

6.10.3 Reviewing and updating pesticide JHAs

A JHA developed for reoccurring projects should be reviewed and evaluated at least annually. The JHA should be reviewed by all team members before initiating each pesticide project. The review process provides an opportunity to determine if the JHA, as written, is adequate for the project. It is also an opportunity to fine tune and incorporate any lessons learned into the JHA. The JHA is a communication and planning tool. It is only as good as the effort spent in preparing it for the project.

6.11 Pesticide cleanup and waste disposal

6.11.1 Cleanup

Application equipment, and mixing and loading areas, must be thoroughly cleaned when an application job is suspended for the day or upon completion. Cleanup should commence in the following order: (1) prepare for safe disposal of all containers and waste materials, (2) wash equipment, (3) clean work areas, and (4) wash yourself.

6.11.1.1 Cleaning equipment

After completing a pesticide application, clean equipment inside and out. Cleaning can be hazardous if not performed correctly. Persons who clean equipment need to know correct procedures, including the appropriate protective clothing and devices to wear. For workers new to pesticide application activities, a preapplication check is advised for equipment cleaning procedures.

Clean equipment at the treatment site, so that wash and rinse water will drain upon the same area where the pesticide was applied (or will be applied the next day).

If equipment cannot be cleaned in the field, or if it is impossible to apply wash and rinse water on the treatment site, clean equipment on a wash rack or concrete apron that has a well-designed sump to store the water. Do not allow the water to contaminate wells, streams, or vegetation. Do not allow water to pool or become accessible to unauthorized personnel, pets, and animals. Follow disposal procedures given in this section or on the product label.

Water and detergent are sufficient for cleaning. Check the JHA, the product label, or the SDS to determine if other washing solutions are required.

Follow the equipment manufacturer's cleanup instructions. Use clean water, and be careful not to damage parts—pumps, screens, and nozzles—that can alter the amount of pesticide applied by the spray rig. Do not clean nozzles with metal objects, which can adversely affect the capacity and spray pattern of the tip; if a bristle brush isn't available, use a round wooden toothpick.

After each day's use, thoroughly flush the sprayer with water, inside and out, and operate the pump to clear lines and nozzles and to prevent corrosion.

6.11.1.2 Mixing and loading areas

Exercise good housekeeping procedures:

- Organize loading areas and inventory to minimize spills and waste
- Prevent the waste of excess pesticide mix by preparing only enough material for the job at hand
- Keep the area neat and clean
- Don't wait until the application is finished to begin cleanup
- Place, in convenient areas, suitable, easily identified receptacles, such as open-top, 55-gal drums for collecting waste material and empty containers
- Collect noncontaminated wastes in separate containers
- Empty contaminated waste receptacles daily or keep them locked in the pesticide storage building overnight
- Follow the procedures discussed in this section when disposing of wastes
- Replace any spill kit supplies used during the day

6.11.1.3 Personal cleanup

Thoroughly wash and dry PPE when it is no longer needed, or when the job is suspended for the day, whichever comes first.

Remove your PPE and place it in a designated area. Assist one another in removing outer protective clothing. Remove chemical protective gloves last, to prevent hands from being contaminated by outer clothing. Pick up contaminated clothing, place them in plastic bags, tie the bags shut with twist ties, and label the bag for disposal or laundering.

Take a shower, thoroughly washing your head, hair, and fingernails with soap and water. After showering, put on clean clothing.

6.11.2 Pesticide waste disposal

Disposal of pesticide wastes includes excess pesticides, containers, contaminated cleanup material, and rinse water. Pesticide disposal is the most significant problem encountered by users. Dispose of contaminated waste materials according to local, State, or Federal regulations. Pesticide-contaminated waste may be regulated as a hazardous waste or a special waste. Check with local, State, or Federal regulators or Reclamations Regional or Area Office Hazmat Coordinators to learn how pesticide contaminated waste is to be handled.

6.11.2.1 Waste-disposal information

Pesticide waste disposal methods vary on a case-by-case basis, depending on the type of waste, a.i. involved, and applicable Federal, State, and local regulations. Generally, wastes can be disposed of by delivering them to either an EPA-licensed pesticide incinerator or an approved landfill. Under certain conditions, waste generators will be given an EPA generator identification number, which shall be included on all disposition forms. To locate an appropriate disposal facility, consult with Reclamations Regional or Area Office Hazmat Coordinators or your local, State, or Federal environmental regulators and request any special disposal procedures for the specific a.i. formulation involved.

6.11.2.2 Pesticide waste groups or lists

EPA regulations (40 CFR 261.33) specify two groups of toxic chemicals that, beginning in April 1986, must be disposed of only in EPA-licensed disposal facilities. The first group is considered "acutely hazardous," and the second group is considered “toxic." Both groups include pesticide chemicals.

6.11.2.2.1 Acutely hazardous pesticides

Pesticides in this group are referred to as "P list" chemicals because they are listed in 40 CFR 261.33 (e). Table 7.1 includes two acutely hazardous pesticides: acrolein (P003) and endothall (P088).

6.11.2.2.2 Toxic pesticides

Pesticides listed in 40 CFR 261.33 (f) are also called "U list" chemicals. Of the pesticides in table 7.1, three are considered toxic pesticide: amitrole (U011), 2,4-D (U240), and xylene (U239).

6.11.2.2.3 Hazardous waste generator

Leftover pesticide product, or excess product deemed a waste, shall be managed as a hazardous waste according to Federal or State regulation. Consult with your Reclamations Regional or Area Office Hazmat Coordinators.

6.11.2.2.4 Other pesticides

Pesticides not included on either P or U lists may be disposed of at non-EPA licensed facilities if the state or local regulatory permitting agencies allows for this disposal.

6.11.3 Pesticide disposal

Mix only the amount of pesticide needed to do the job. However, if an excess occurs, put remaining pesticide in clearly marked, leak-proof containers.

Many pesticide distributors provide products in returnable containers that can be recycled. Check with the distributor before purchasing the product. Disposing of pesticide containers can be a significant problem, especially if a large number of them piled up during an application and were not washed out properly during mixing. It is important to triple rinse containers prior to disposal. Triple-rinsed containers are not considered hazardous waste. Pesticide rinsate from container cleaning may be used as a diluent for mixing of additional material; otherwise, the rinsate must be collected and treated as a hazardous waste.

Even after triple rinsing, however, containers are still hazardous; they contain enough pesticide to render them unsafe for any use. Don't put other pesticides in them, and don’t reuse the container. If the containers are metal or plastic, perforate and crush them. Deliver all containers to an approved disposal facility or store them in plastic bags in a locked building until disposal.

Contact Reclamations Regional or Area Office Hazmat Coordinators for information for the proper disposal requirements.

6.11.3.1 Disposal of rinse water

Rinse water disposal is a special problem, mainly because of its quantity. There are few equipment cleaning sites available that are designed to contain large volumes of rinsate liquid. If equipment cleaning instructions previously noted are followed, and rinse water is applied to treatment areas, disposal problems can be significantly reduced. If water is not applied to treatment areas, it will have to be collected in a sump or with absorbent material, and placed in leak-proof containers for disposal.

If the pesticide involved is either a P- or U-list chemical, the rinse water must be delivered to an EPA-licensed disposal facility.

Contact Reclamations Regional or Area Office Hazmat Coordinators for information for the proper disposal requirements.

6.11.3.2 Treatment, storage or disposal facilities (TSDF)

Reclamations Regional or Area Office Hazmat Coordinators can help identify approved Federal or State approved and permitted TSDF for material contaminated with each product that needs to be disposed of. Local, State, or Federal environmental regulators can furnish a list of facilities for pesticide wastes that require licensed facility disposal.

When a disposal facility is identified, determine the disposal requirements for the TSDF before delivering pesticide waste materials.

6.12 Pesticide spills

Identify places and operations where spills may occur, such as during handling, mixing, and loading; in storage sites; and during transport. Develop coordination with local organizations that may be equipped and trained in spill response, such as fire departments, county law enforcement, and State police. Develop emergency spill plans. If a spill occurs, the spill plan will save valuable time, as well as effectively reduce environmental damage. Keep emergency spill kits readily accessible for responding to and cleaning up spills. Post emergency telephone numbers near appropriate telephones. Employees need to be trained in accordance with OSHA’s Hazardous Waste Operations and Emergency Response regulations (HAZWOPER) in the procedures for spill cleanup, decontamination and disposal.

6.12.1 Spill cleanup plan

Each project shall have a written emergency spill plan for responding to large spills; (i.e., spills that require more than two persons to clean up, spills that take longer than a few minutes to clean up, or spills that involve restricted use pesticides). The JHA focuses on safety procedures related to specific pesticide

applications, and the spill cleanup plan contains safety procedures to be implemented whenever a spill emergency occurs in a defined organizational unit. The spill cleanup plan, therefore, covers all pesticides in inventory.

Following spill plan procedures saves valuable time and effectively reduces environmental damage. More importantly, the spill plan is an invaluable training aid for spill response and cleanup techniques, and for familiarizing new employees with emergency devices, equipment, and information.

As a minimum, spill plans should:

- Provide spill notification instructions
- Designate a HAZWOPER trained spill cleanup team
- Inventory all stored pesticides
- Enumerate special precautions associated with the pesticides
- List approved disposal sites
- Contain diagrams of areas where spills are more likely to occur
- List sources of emergency supplies and equipment
- Provide guidance for recognizing symptoms of poisoning, and
- Provide location of spill cleanup equipment and PPE

6.12.1.1 Spill cleanup team

All pesticide workers must be trained in cleaning up spills according to OSHA's HAZWOPER regulations. Every role and responsibility of the spill cleanup team should be clearly defined, from team leader to cleanup workers, and all should be trained to respond as a team. Once a spill cleanup team has been designated, list their names, normal work station telephone numbers, off-duty telephone numbers and HAZWOPER training and date of training. List their work hours if shift work occurs.

6.12.1.2 Notification instructions

The plan should list the name, affiliation, and telephone number of the appropriate person to contact in the event of a spill. Include on the list:

- Job supervisor, if available, or alternate
- Safety officer(s) responsible for the project if they are not located at the project
- Reclamation regional or local safety officer if spill occurs on Reclamation lands or facilities
- Designated on-scene spill cleanup coordinator

- Reclamation Regional or Area Offices Hazmat Coordinator if spill occurs on Reclamation lands, facilities or projects.
- Local medical facilities with staff familiar with pesticide poisonings
- National Response Center hotline, telephone: 800-424-8802
- State Environmental Regulatory Agencies Spill Notification
- Designated State pesticide coordinator
- State and local police and local fire departments
- Occupied buildings near storage, mixing, and loading, and application sites, as well as downstream users of water projects
- Sources of additional cleanup equipment and operators

6.12.1.3 Pesticide inventory

The spill plan must contain a complete inventory of all currently stored pesticides. The plan must list the amount of each product, with the following information about each product:

- Manufacturer's name, address, and emergency telephone number
- Product name, common name, and EPA registration number
- Special precautions.—For each pesticide, check the SDS
- Flash point
- Ignition temperature
- Toxicity
- Solubility
- Vapor density (pressure)
- Specific gravity
- Need for special extinguishing or decontaminating agents

For each product, note any special precautions and where to locate devices, equipment, or materials needed to observe the precautions.

6.12.1.4 Disposal sites

Identify permitted and approved disposal sites for material contaminated with each product stored. For each site identified, list address, telephone number, permit number and contact person.

6.12.1.5 Critical area diagrams

Draw reasonably accurate, up-to-date diagrams of areas where greater chances of spills exist (i.e., storage buildings, loading and mixing sites, freight docks, etc.). Indicate exterior runoff patterns, nearby water sources (wells, lakes, streams, and dry creek beds), drains, fire mains, location of pesticides, and location of spill kits or other emergency response gear.

- Show pesticide locations within the facility.
- Emergency Supplies and Equipment
- State where additional absorbent material can be found.
- Note where a front-end loader and heavy equipment can be obtained.
- Describe other materials available for emergency cleanup.
- List telephone numbers for each item.
- Indicate the lead time necessary for delivery or arrival of material.
- Symptom Surveillance
- Summarize the symptoms of poisoning for each product.
- Describe what to do if poisoning is suspected.
- Note location of medical treatment facilities.

6.12.1.6 Maintaining spill cleanup plans

- Update the plan annually and at any time a new pesticide product is added to the project's inventory.
- Revise the plan for current information.
- Bind copies in clear protective covers and prominently display in storage facilities, at mixing and loading sites, and at other appropriate locations.
- Provide copies to the Reclamation project safety officer, regional safety officer, Regional and Area Office Hazmat Coordinators and regional pesticide coordinator.
- Train all workers, especially new employees, in the plan's contents and use.

6.12.2 Spill kits

- Kits should be designated for use in pesticide spills only.
- Place near areas where pesticides are handled, stored, mixed, and loaded, or where spills are likely to occur.
- A spill kit should also be provided with the application equipment.
- Spill kits will need to be inventoried intermittently to ensure that spill kit materials are available when needed.

- Label each kit with a list of contents.
- To deter pilfering, seal kit with a soft wire - do not inhibit access in an emergency.

6.12.2.1 Stationary spill kits

Place stationary spill kits at mixing and loading sites, next to storage facilities, and at other locations where large amounts of pesticides are handled.

Items included in the spill kits will depend, to some extent, on the pesticide products that are stored, whether pesticides are dry or liquid formulations, and what type of container pesticides are stored in.

6.12.2.2 Mobile spill kits

Place mobile spill kits in trucks and other vehicles that transport pesticides. Items included in the kits will depend on the pesticide products that are transported. Table 12.2.2 lists the contents that are suggested for stationary spill kits and mobile spill kits. The quantities of material, such as PPE, will vary according to the expected size of the workforce involved.

Table 6.12.2.2.—Suggested contents for spill kits

Contents for Stationary Spill Kits	Contents for Mobile Spill Kits
Copy of the JHA	Copy of the JHA
Personal protective equipment: Nitrile gloves or garden hose (150 feet) Nitrile boots Coveralls or spray suits Goggles Respirators and cartridges	Personal Protective Equipment: Nitrile gloves Nitrile boots Coveralls or spray suits Splash goggles Half- or full-face negative pressure respirators, equipped with cartridges that are suitable for the emergency situation
Open-top, 55-gallon drum	Dust pan, shop brush
Plastic (polyethylene) tubing (1/2 inch, 30 feet)	Synthetic-fiber push broom
Plastic (polyethylene) tarpaulin	Square-point shovel
Plastic rope (100 feet)	Plastic (polyethylene) tarpaulin
Red flagging	Traffic-control flags
Liquid detergent (1 gallon) 5 percent	Liquid detergent (pint or more)
Dust pan, shop brush	Absorbent material (30 pounds)
Synthetic-fiber push broom	Plastic (polyethylene) bags, with ties
Square point shovel	Self-adhering bag labels or tags
Pipe wrench (18 inches) and bung wrench	Class 2A40B fire extinguisher
Drum pump (manual), drum spigot, and bungs (2-1/2 inches and 3/4 inch)	Portable eye washer
Solution bleach (3 gallons)	
Absorbent material (80 pounds; sawdust, cat litter, or similar)	
Plastic (polyethylene) bags, with ties	
Self-adhering bag labels on tags	
Class 2A40B fire extinguisher	

6.12.3 Spill containment

When a large spill occurs, call for help immediately. Once the call is made, and only if another qualified person is present, begin by containing the spill. If you are alone, secure the area and wait until help arrives. Never work alone; always work within sight of another person.

Contain as much spilled pesticide as possible. Keep it from entering storm drains and water systems. If the spill occurs on the road or highway, keep the pesticide on the pavement and divert traffic, if possible. Unless the pesticide spill occurs on a concrete apron with a sump, do not hose it down. Unrestricted water will scatter the chemical, increase environmental contamination, and prolong cleanup activities.

Pesticide spills can liberate toxic gases or vapors. Always work in a well-ventilated area. If work is in an enclosed area (shop, storage building, etc.), mechanically ventilate the area with intrinsically safe mechanical ventilation. If the spill takes place indoors, open doors and windows to reduce accumulation of gases and vapors. If an area cannot be ventilated, or if a JHA or spill plan requires special devices, do not proceed until a SCBA is available.

Put on appropriate PPE from the spill kit. This includes splash goggles, negative pressure half- or full-face respirator (when needed), nitrile gloves and boots, and coveralls or spray suit. Prevent ignition of flammable materials by eliminating all sources of ignition. Shut off gasoline engines and electric motors, such as exhaust fans, welders, and bench tools. Stop smoking cigarettes, cigars, and pipes. Rope off the area. Use red flagging or post warning signs to keep unprotected persons from entering.

Encircle the spill with a dike of absorbent material, or, as a last resort, use sand, soil, or rags. If necessary, dig a ditch to direct the spill flow away from drains, water sources, or other sensitive areas. Cover liquid spills with absorbent material; cover dry material spills with a plastic tarpaulin and secure it.

If the spill involves a waterway, dig a ditch to divert the flow of uncontaminated water around the spill, if possible. If this is not possible, construct an underflow dam to filter the water and collect as much of the spilled material as possible. For a small waterway, use activated charcoal to construct and make the dam. For a large waterway, construct the dam from baled straw.

Notify the pest control supervisor, the person responsible for the application, or an environmental health and safety officer. In addition, if the spill occurred on a highway or other public area, follow the procedures for reporting a spill on a public area.

6.12.3.1 Spills of dry material

Immediately cover dusts, granules, or powders with a plastic tarpaulin to prevent the material from becoming airborne. Spreading also can be minimized by dampening the material with a fine mist of water; however, do not dampen enough to cause water runoff or puddling. Clean up by rolling the tarpaulin back, little by little, as you sweep. Shovel the material into a drum or plastic bags. Seal the drum or bags and label them. Set them aside for disposal later, or for relabeling if the pesticide still can be reused.

6.12.3.2 Spills of liquid material

Pump as much of the spilled liquid as possible into containers. Cover the remaining portions with an absorbent material. Use only enough material to absorb the spill. Spread the absorbent material around the perimeter of the spill and sweep toward the center. Shovel the absorbent material and pesticide into leak-proof containers, label them, and set them aside for disposal.

6.12.4 Decontamination

After cleanup, the small amount of pesticide remaining on a concrete floor, paved road, or steel truck bed may need to be decontaminated or neutralized. Most pesticides are rendered relatively harmless by washing with water and detergent. Other pesticides may need to be treated with one of four specific agents, as necessary. The agents are called decontaminants. Refer to the product label or SDS, or contact the manufacturer, to ascertain whether decontamination is needed, and which decontamination is appropriate for the spilled product. Do not store decontaminants in the same building with pesticides. The five decontaminants are detergent, alkali, acid, oxidants, and reducing agents.

The following guidelines for decontamination of soil, roadways, tools, and nonporous surfaces appear below.

6.12.4.1 Soil

Remove contaminated soil to a depth of 2 inches (50 millimeters [mm]) or more below the contamination zone; place soil in labeled drums or plastic bags for disposal.

6.12.4.2 Nonporous surfaces

Spread cleaning material on the spill area and work it into the surface with a coarse broom. Leave and allow the decontaminant to be undisturbed for at least 2 hours. Pick cleaning material up by spreading fresh absorbent around the spill perimeter, sweeping it toward the center, and shoveling into plastic bags or drums for disposal. Repeat the decontamination process. After the second sweeping, dike and rinse the area with water. Collect the rinse water for disposal using absorbent material.

6.12.4.3 Tools and vehicles

Soak tools in a cleaning solution for 2 hours and rinse with water. Wash the tools with detergent and water. Collect the rinse and wash water for disposal. Do not move a vehicle involved in a spill until it has been cleaned and decontaminated. If the vehicle is on a nonporous surface, dike and collect the wash water for disposal. If the vehicle is on soil, after washing follow the soil decontamination procedures above.

6.12.4.4 Porous material

Dispose of contaminated porous material such as brooms, leather shoes, and wooden items. They cannot be decontaminated.

6.13 Pesticide fires

6.13.1 Preparation

- In accordance with SARA Title III, inform the local fire departments of the chemicals that are stored and their location. Provide pertinent information to the fire department for emergency preparation and planning. In addition:
- Ensure that fully charged fire extinguishers are in spill kits and are at appropriate locations.
- Use class 2A40BC, dry chemical fire extinguishers for fighting pesticide fires, unless the SDS instructs otherwise.
- Ensure persons fighting pesticide fires wear PPE to guard against smoke, gases and vapors; water, mist, spray, and runoff.
- Ensure PPE is available in spill kits.
- Ensure spill kits and backup spill kits and supplies are readily available.

6.13.2 Fighting fires

- Attempt to extinguish the fire and contact the fire department.
- Stay up hill and up wind of the fire
- Provide the fire department with an SDS to assist them in fighting the fire
- Notify your immediate supervisor.

- Keep the public upwind and away from areas where they might be exposed to smoke, fumes, gases and vapors, and runoff.
- Minimize personal exposure by approaching the fire upwind and from a safe distance
- Stay clear of drums, cans, and bottles that may explode from overheating.
- Prevent the fire and pesticide from spreading.
- Use water to cool nearby pesticide containers.
- Move vehicles and mobile equipment away from the fire or cool them with water.
- Construct dikes (if possible) if water is the only available suppressant, to prevent excess water from contaminating the surrounding area.
- Apply water with a fog nozzle or a dispersed stream. A straight stream of water will spread the fire by scattering the burning pesticide.

6.13.3 Cleanup

Cleanup should take place immediately after the fire is out. Dispose of ashes, impounded water, and material used for dikes as contaminated waste. Federal and State Environmental Regulatory agencies might provide oversite of all cleanup activities.

6.14 Vehicle accidents

If a vehicle transporting pesticides is involved in an accident, implement the following five steps immediately: (1) rescue occupants, (2) suppress fires, (3) secure the area, (4) report the accident, and (5) perform cleanup and decontamination. The five steps are discussed in more detail below.

6.14.1 Rescue occupants

- If the driver and other occupants are conscious and not seriously injured, help them move a safe distance from the wreckage.
- If any occupants are unconscious or seriously injured, do not move them unless the vehicle is on fire.

- Check the ABC's:
  - (A)irway obstructions
  - (B)leeding
  - (C)onciousness.

6.14.2 Fire Suppression

- Extinguish any fires.
- Eliminate any sources of ignition.

6.14.3 Secure the area

- If pesticides have been spilled, detour oncoming traffic away from the scene.
- Cordon off the area.
- Prevent any unauthorized access to the spill area.
- Stay up hill and up wind from the fire if material is burning.

6.14.4 Accident report

- Call 911 or the appropriate emergency service agency serving your community. Provide the following information to emergency service agencies:
- Who you are and who you represent.
- What happened, when, and where it happened?
- Extent of injuries, if any.
- DOT classification, name, and quantity of the pesticide involved.
- The accident location (including address and telephone number) and the location and telephone number you are calling from. When emergency help arrives, share any information you have about the pesticide with them.

6.14.5 Cleanup and decontamination

Cleanup and decontaminate the spill according to internal cleanup procedures and local, State, or Federal regulations.

6.14.6 Spill and accident reporting requirements

All spills or accidents must be reported to the local Reclamation supervisor, Reclamation Regional or Area Office Hazmat Coordinator, and the health and safety manager. Further notification requirements are outlined below.

6.14.6.1 National response center

Notify the National Response Center when pesticide spills equal or exceed the reportable quantity (see table 14.6.3).

The technical form of a pesticide chemical consists of 100-percent active ingredient. Thus, if the reportable weight of an active ingredient is 1 pound and the formulation contains 50-percent active ingredient, the reportable weight of spilled product would be 2 pounds; for a 25-percent solution, 4 pounds; and for a 5-percent dust, 20 pounds. If the product contains more than one hazardous substance—for example, 2,4-D and dicamba—calculate the weight of each substance to determine if reporting is required. Note that more than 1,000 toxic substances are listed in the regulation; if the active ingredient of the spilled pesticide does not appear in tables 8.2.1 or 14.6.3, check 40 CFR 302.4 before assuming the spill does not need to be reported to the National Response Center.

6.14.6.2 Notification state environmental regulatory agencies

Notify the State Environmental Regulatory Agency spill notification phone number when pesticide spills equal or exceed the state reportable limits.

Every state environmental regulatory agency will have its own notification requirements.

Coordinate with Reclamations Regional or Area Office Hazmat Coordinators for state notification assistance.

6.14.6.3 Bureau of Reclamation reporting requirements

If any of the following accidents occur on Reclamation lands or facilities, report them immediately to the responsible Reclamation supervisor, Reclamations Regional or Area Office Hazmat Coordinator, and the health and safety manager. The accident shall be reported through the Safety Management Information System (SMIS) at www.smis.doi.gov/ If the accident cannot be reported through SMIS, the following information will be collected and recorded in SMIS at the earliest possible time.

Table 6.14.6.3.—Hazardous substances and reportable weights

Common name	Reportable weight hazardous substance of active ingredient (lb)[1]
Acrolein	1
Amitrole	1
Ammonium sulfamate	5,000
Carbaryl	100
Chlorpyrifos	1
Copper sulfate	10
Diazinon	1
Dicamba	1,000
Dichlobenil	100
Diquat	1,000
Diuron	100
Endothall	1,000
Malathion	100
2,4-D acids, esters, or salts	100
Xylene	100
ICR substances[2]	100

[1] 1 lb = 454 g

[2] ICR denotes ignitable, corrosive, and reactive substances.

A description of the events pertaining to the accident (who was involved in the accident; what circumstances happened that led up to the accident; when the accident occurred; where the accident occurred; and the nature of the injuries or property damage that occurred, if any).
Report any instance of:

- Injury, illness, or death of a person that results from pesticide activities on Reclamation land or facilities
- Accidents involving vehicles carrying pesticides
- Accidental dumping or spilling of pesticides, and pesticide fire
- Contamination of the environment, including humans, farm animals, wildlife, trees and crops, homes, or public or private property
- Any potentially significant episode, such as off-target movement of an applied pesticide

Serious Accidents. For reporting purposes, serious accidents are defined as accidents in which any of the following occur:

- An employee (including a contractor's employee) suffers death, permanent total disability, or loss of an eye, hand, foot, or major organ.

- Five or more employees or contractor’s employees are hospitalized, or one is hospitalized in critical condition.

- Fires or property damage resulting in a loss of $25,000 or more.

- Third-party injuries, or death, or substantial property damage or loss that may result in claims against the Government.

- Death or serious injuries to other than Reclamation employees on facilities under Reclamation control.

Serious accidents must be reported immediately by telephone to the Reclamation regional safety manager or designee. Immediately after reporting the accident, secure the equipment involved and the site where the accident occurred until a regional safety investigation team arrives to investigate the accident.

6.14.7 Accident investigations

Immediately following an accident, the employer should appoint an accident investigation team. Employees familiar with the accident, but not part of the investigating team, may need to assist the team with the investigation. Provide the following information:

- Safety plan under which the project was operating at the time of the accident, including the JHA for evaluating hazards and the standard operating procedures determined in developing the plan.

- Basic information on the pesticide, including a copy of the pesticide label, a SDS, and the quantity involved in the accident; drawings and descriptions of the canal, drainage ditch, dam, or other structure treated; the pest or pesticides involved; ownership of property involved; other public agencies involved, if any; and the individual in charge of the work.

- Application information, if at variance with the JHA, including date and time pesticide was applied; method of application; name of applicator; pesticide formulation; application rate; any special safety precautions taken; and any special circumstances, such as applications made under EPA registration waivers or experimental-use permits.

- If humans were hurt or contaminated, provide a written statement from attending medical practitioner, the victim's involvement in the project, and the victim's job experience

- If domestic animals were hurt or contaminated, provide a statement from the attending veterinarian.

- Any information pertinent to the accident, such as use of warning placards, watchmen, or other forms of public notification; news articles about the incident; unusual circumstances, including adverse weather at the time of the accident; and whether similar incidents have occurred recently in the same area

6.15 Poisoning

Surveillance is one of the most important and necessary activities undertaken whenever workers use or handle pesticides and other hazardous materials. If poisoning occurs, contact the National Poison Control Center at 1-800-222-1222.

6.15.1 General symptoms

Early, general symptoms of pesticide poisoning include fatigue, headache, dizziness, nausea, and vomiting. The degree to which a person has been exposed to the pesticide will determine, to a certain extent, the intensity of the symptoms, quickness of onset, and manifestation of additional symptoms.

If a worker recognizes pesticide poisoning symptoms in himself or a coworker, seek first aid (or provide it to a coworker) and seek medical attention. Two kinds of symptoms are indicative of pesticide poisonings. Only a victim can notice internal symptoms such as headaches, nausea, burning pain in the chest and stomach, raspy throat, and malaise. Other symptoms outwardly visible to those who have been poisoned and their coworkers include sweating, vomiting, and skin blisters. Monitoring workers who use pesticides requires more than simple observation. Periodically, applicators should be asked how they feel.

In addition, symptoms may result from both the toxicity of the poisoning, and the route of entry the poison took, as well as the characteristics of the a.i. Symptoms are of three broad classes: (1) internal-injury symptoms, resulting from pesticides absorbed into the body by oral, dermal, and inhalation routes;

external-injury symptoms, resulting from chemical action on the skin or eyes; and (3) combinations of symptoms indicating combinations of internal and external injuries.

6.15.2 Internal injury symptoms

Internal poisonings injure body organs, such as the liver and kidneys, and nervous or circulatory systems. Usually, poison enters the body by inhalation, ingestion, and skin or eye absorption. Symptoms of internal injury include headache, dizziness, and nausea.

6.15.3 External injury symptoms

External injuries usually result from irritation after contact with the pesticide. Symptoms of external injuries include redness, rashes, and blisters on the skin, and/or and stinging and burning sensations in eyes, nose, mouth, and throat.

6.15.4 Chemical group symptoms

Individual pesticides belong to chemical groups, or families, based on the molecular structure of their a.i. Chemically similar pesticides have a similar toxicology, or mode of action, in the way they affect humans. Symptoms are the body's reaction to the toxicology of the poison. For example, a chemical group that injures the liver could produce expected symptoms such as cirrhosis or jaundice, or if the chemical group irritates mucous membranes, any of the chemicals in the group could cause pain in breathing, or swollen or sore nasal passages, or both.

6.15.5 Poisoning symptoms of common pesticides

Table 15.5 lists symptoms of pesticide poisoning. Chemically similar pesticides have been grouped and chemical group symptoms are given. Note that many of the symptoms listed are similar to those for other illnesses or conditions (such as the flu) or the onset of a more serious illness (such as hepatitis). Only a physician can diagnose pesticide poisoning, particularly when only internal symptoms are known.

Table 6.15.5.—Symptoms of pesticide poisoning

Chemical group and common name	Toxicology or mode of action on humans	Symptoms of internal exposure	Symptoms of external exposure
Organophosphates Chlorpyrfos Diazinon Malathion	Inhibits cholinesterase Enzymes	Headache, dizziness, weakness, shaking, nausea, stomach cramps, diarrhea, sweating	Minimal rashes; readily absorbed through the skin
Carbamates Carbaryl Beniocarb	Inhibits cholinestrase Enzyme	Headache, dizziness, weakness, shaking, nausea, stomach cramps, diarrhea, sweating	Minimal rashes; readily absorbed through the skin
Chlorinated Hydrocarbons Chlordane dicofol[1]	Disrupts nervous system; impairs brain function	Headache, dizziness, weakness, shaking, nausea, excitability, disorientation	Minimal rashes; readily absorbed though the skin
Chlorophenonxys 2,4-D	Irritates lungs, stomach and intestinal linings; injures nervous system, kidney, and liver	Prompt vomiting, burning sensation in stomach, diarrhea, muscle twitching	Moderately irritating to eyes, skin, and lungs
Quaternary ammonium salts Diquat	Injures cornea, liver, kidneys, intestines and stomach linings, respiratory system, and skin	Burning pain, nausea, vomiting, and diarrhea	Irritates skin
Pyrethrins and pyrethroids Resmethrin	Very low toxicity to humans	Slight toxic reaction	
Anticoagulants Brodifacoum Chlorophacianone Diphacinone	Prevents blood clotting	Usually no reaction if a low dose is ingested	Minimal
Acrolein	Strongly irritates throat and lungs	Headache, dizziness, nausea, wheezing, coughing	Severely irritates eyes, nose, and throat; blisters skin
Copper salts and complexes	Injures kidneys, liver, intestinal lining, blood, and brain	Prompt vomiting, burning pain in chest, diarrhea, headache, sweating	Irritates skin and eyes; damages mucus membranes
Heterocylic compounds Endothall	Damages heart, blood vessels, nervous system, and intestinal lining	Convulsions, shock, lack of coordination	Irritates skin, eyes, and mucus membranes
Sodium acids Dichlobenial	Irritant		
Benzonitriles Dichlobenil	Irritant	Moderately irritates lungs	Moderately irritates skin
Dinitrotoluidene compounds Oryzalin Trifluralin	Irritant		Slightly to moderately irritates skin, eyes, nose, and throat
Glycine derivative Glyphosate	Irritant	Irritates lungs	
Triazines Ametryn Atrazine Prometion Simazine	Irritant		Mildly irritates skin, eyes, nose, and throat
Uracils Bromacil	Irritant	Irritates lungs	Irritates skin, eyes, nose, and throat
Urea derivatives Diuron	Irritant		Moderately irritates skin, eyes, nose, and throat

[1] Chlordane: *Federal Register*, v. 53, No. 68, April 8, 1988, p. 11798. (1) The sale, distribution, and commercial use of chlordane pesticides are prohibited after April 15, 1988; (2) these prohibitions apply to all manufacturers' chlordane products; and (3) they apply to the use of chlordane products now held by Government agencies, irrigation districts, and other entities.

6.15.6 Solvents

In many pesticide products, solvents are combined with a.i. to promote application efficacy. Two common solvents are kerosene and xylene.

6.15.6.1 Kerosene and fuel oil

Kerosene (coal oil) or fuel oil may constitute as much as 98 percent of concentrated pesticides. They are highly refined, essentially odorless petroleum products. Primary routes of solvents entry are inhalation, ingestion, and skin absorption. Effects of exposure include depressive action on the central nervous system, sometimes preceded by excitement. Liver and kidney damage occur in severe cases. Inhalation often produces headache, blurred vision, dizziness, or nausea.

6.15.6.2 Xylene

Xylene is a common solvent in many pesticides, and it also is used alone as an aquatic herbicide. Xylene severely irritates mucous membranes and skin. Signs of poisoning are similar to those of kerosene poisoning, coupled with more severe mucous membrane irritation.

6.16 First Aid

Before administrating first aid, read the instructions on the back of the JHA form, pesticide product label, or SDS. The chemistry and formulation of the specific pesticide product and the kind of exposure the victim has had will determine the specific first aid procedures to be applied.

6.16.1 General first aid

Persons exposed to pesticides should stay calm. Serious effects are not instantaneous for most pesticides. If an individual has been exposed to a highly toxic pesticide and is beginning to feel the effects, immediately take the victim to a medical facility, along with the product label and SDS. Never give a poisoning victim any form of alcohol.

6.16.2 Specific first aid

Proper first aid techniques depend on the type of exposure a victim has had. Exposures can be singular or multiple in nature. For example, if the victim has been exposed to pesticide fumes, inhalation exposure is likely the only exposure

that occurred. If the chemical was splashed on one's face, the victim may have any combination of eye, skin, and oral exposure. Analyze the situation carefully and apply first aid techniques for all exposures that have occurred.

6.16.2.1 Dermal exposure

- When pesticide splashes on the skin, scrub the exposed area thoroughly with soap and water. Time is crucial to reduce both external injury and absorption of the poison.
- Remove all clothing that has been contaminated.
- Wash the contaminated area (skin, hair, fingernails, etc.) thoroughly with soap and water.
- If one has been splashed with material readily absorbed by the skin (such as carbamates, chlorinated hydrocarbons, chlorophenoxy compounds, or organophosphates), scrub victim a second time with soap and fresh water.
- Scrub the victim a third time with soap and water.
- After the third washing, take the victim for medical treatment.
- If a person burns their skin with chemicals, remove the contaminated clothing and wash the burn area with large quantities of running water. After washing, cover the area with loose, clean cloth. Do not treat with ointments, greases, powders, or other topical drugs. Treat for shock. Keep the victim flat, warm, and reassured until professional medical care is available.

6.16.2.2 Eye exposure

- Flush eyes immediately with copious amounts of water. In remote areas, the vehicle spill kit shall contain an emergency eye washer. Use the emergency eye wash according to the manufacturer’s instructions.
- If an emergency eye washer is not available
- Hold the eyelids open.
- Flush the eyes with a gentle stream of clean running water for at least 15 minutes. Make sure the wash water is free of chemicals; contaminants can increase the severity of injury.
- Once the eyes have been thoroughly flushed, take the victim for medical attention.

- Inhalation Exposure
- Carry or drag the person; don't allow the victim to walk to fresh air.
- Loosen clothing and administer CPR if breathing has stopped or is irregular.
- If the victim is convulsing, monitor breathing. Keep the victim's chin raised, so the air passage will remain free for breathing.
- Wrap the person in a blanket to prevent chilling. Keep the victim quiet.
- Take the victim to medical treatment.

6.16.2.3 Oral exposure

If someone swallows a pesticide, determine whether to induce, or not induce, vomiting, or to administer an emergency antidote. Usually, antidotes are administered only by trained medical professionals; however, the product label or SDS may give instructions to administer one. If an antidote is recommended, give it immediately if the victim can swallow. Take the victim immediately to medical care.

Product safety literature will instruct to either "induce vomiting at once" or "do not induce vomiting."

If the instructions recommend vomiting, force the victim to vomit at once, unless he or she is unconscious or in convulsions.

- For an adult, induce vomiting with two tablespoons (one ounce) of "Syrup of Ipecac" and two glasses of water.
- For a child, use one tablespoon (one-half ounce) of "Syrup of Ipecac" and one glass of water.
- If Syrup of Ipecac is unavailable, vomiting may be induced by drinking 1 or 2 glasses of water and pressing the back of the throat with a finger.
- The victim should be lying face down or kneeling while vomiting. This prevents the vomit from being swallowed or entering the lungs and causing further damage.
- Collect some of the vomit in a disposable cup and take it to the hospital with the victim; the attending physician may need to test it.
- Do not spend a great deal of time attempting to induce vomiting.

- Get the victim to the hospital as quickly as possible.
- If the label identifies a specific antidote, this information is intended for use by a doctor.

Neither atropine nor 2-PAM should be taken as a prophylactic. They do not prevent poisoning. Nor should workers carry atropine or 2-PAM capsules or tablets for first aid. Oral atropine has no place in a poisoning emergency. It can mask or delay poisoning symptoms, giving a false sense of security and, perhaps, allowing dangerous exposure to continue.

6.16.3 First aid kit

All pesticide work parties must have a specifically prepared first aid kit readily available.

In addition to the contents found in kits for industrial and vehicle accidents, the first aid kit should contain basic first aid supplies for any pesticide poisoning emergency. The kit should have specific supplies for accidents that involve the product being handled or applied. Rely on the product label or SDS for information on specific supplies. Replenish used contents or replace the kit if the expiration date has lapsed. When stocking the kit, check with Reclamation health and safety professionals for guidance.

The first aid kit should contain the following items:

- Liquid detergent or soap
- Emetic or Syrup of Ipecac
- Soft blanket to cover shock victim
- Disposable drinking cups
- Sterile cloth to cover burns
- Clean water for washing and drinking
- Eyewash solution
- Particular items will be required by the product label or SDS. Items may include one or more nonmedical antidotes such as baking soda, milk of magnesia, lemon juice or vinegar, and powdered activated charcoal.

6.17 Medical attention

The JHA will list the name, address, and telephone number of the physician, as well as the clinic or hospital that will provide care in the event of a poisoning. The 911 number, if available, will summon a rescue squad or ambulance. Call the

medical provider listed on the JHA immediately after exposure occurs. Provide the following information to emergency personnel:

- Who you are, and why you are calling
- Where you are, including the telephone number you are calling from
- Condition of the victim (conscious, vomiting, delirious)
- Name of the chemical the victim was exposed to
- Kind of exposure (inhalation, absorption, ingestion, or injection)
- Approximate amount of time it will take to get the victim to the medical facility

Consult your JHA for directions to the medical facility. Verify this information with emergency personnel. Do not hang up. Let the clinic or hospital end the conversation. The purpose of the call is to provide the medical facility with information necessary to prepare for the victim's arrival. The clinic may need time to check with a poison control center for the preferred treatment. They may have questions about the pesticide if they are unfamiliar with it.
If an ambulance or rescue squad vehicle is used, make certain the driver knows where to take the victim. In any case, a coworker or supervisor should accompany the victim.

Ensure a copy of the product label or the SDS accompanies the victim to the medical facility.

6.18 Medical surveillance program

Pesticide applicators and workers whose duties involve storing, handling, mixing, applying, and disposing of pesticides are required to be enrolled in the medical surveillance program (preexposure, periodic, and postexposure medical examinations). The examinations shall be performed, at Government expense, by licensed physicians who are board certified or board eligible in occupational health medicine.

Persons exposed to cholinesterase-depressing chemicals (carbamate and organophosphate) are required to have baseline blood-cell cholinesterase examinations before the application season begins and monthly during the season. Persons exposed to other pesticides shall have examinations as appropriate to the specific hazards of the product, as determined by an occupational health medicine physician. As a minimum, liver and kidney function tests and a complete blood analysis should be performed annually, or as necessary, to characterize an employee’s exposure.

6.18.1 Initial examinations

Initial preexposure or pre-employment examinations should include:

- A medical and work history
- Physician-administered physical examination specific to pesticide exposure
- Examination of the hepatic and renal systems
- Chest x-ray (as required by the attending physician)
- Spirometry
- Comprehensive and specific chemical, blood, and urine profile specific for pesticides
- Liver function tests specific to pesticide exposure
- Renal function tests specific to pesticide exposure

6.18.2 Follow-up examinations

Personnel shall receive medical examinations at least annually, except when additional examinations are deemed appropriate by an environmental health and safety or medical professional.

6.19 Protecting the public

Sites that are to be treated with pesticides shall be posted according to the pesticide label. Posting shall be at normal points of entry to inform the public of possible exposure and re-entry restrictions. In addition, the public must be notified before aerial application of a pesticide per Reclamation D&S ENV 01-02. For example, if the treatment area is near heavily used public areas, such as roads, practitioners may coordinate with local authorities for temporarily closing or detouring traffic around target and staging areas.

7. AUTHORITIES, REGULATIONS, AND POLICY

Reclamation is required by Federal law, regulations, Executive Orders, and policy to control and manage pest and invasive plants and animals.

Implementation Authorities for IPM and Invasive Species at Reclamation

Reclamation operates under the following implementing authorities for invasive species and IPM. A detailed summary of each is described below.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947, as amended (FIFRA)

The FIFRA regulates the manufacture, registration, labeling, use, storage, and disposal of pesticides, and as promulgated by Environmental Protection Agency (EPA) regulations found at 40 CFR Parts 150-189. Under FIFRA, States are required to establish programs to certify pesticide applicators. Upon approval by the EPA, Federal agencies and Indian reservations may also establish programs to certify pesticide applicators.

FIFRA was amended by the Food Quality Protection Act of 1996, and states, in part: “Federal agencies shall use Integrated Pest Management techniques in carrying out pest management activities and shall promote Integrated Pest Management through procurement and regulatory policies, and other activities.”

Reclamation Act of 1902, as amended

The Reclamation Act established the Reclamation program to develop the arid West by promoting farming opportunities for families and limiting speculation on land that would benefit from the introduction of irrigated agriculture, as amended by the Reclamation Reform Act of 1982.

Carlson-Foley Act of 1968, as amended

The Carlson-Foley Act directs Federal agencies to enter upon lands under their jurisdiction having noxious plants and to destroy noxious plants growing on such lands.

Fish and Wildlife Coordination Act of 1934, as amended (FWCA)

FWCA provides the basic authority for the U.S. Fish & Wildlife Service's (USFWS) involvement in evaluating impacts to fish and wildlife from proposed water resource development projects. The FWCA requires that fish and wildlife resources receive equal consideration as other project features. The FWCA also requires federal agencies that construct, license or permit water resource development projects to first consult with the FWS (and the National Oceanic and

Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) in some instances) and State fish and wildlife agencies regarding the impacts on fish and wildlife resources and measures to mitigate these impacts. FWCA was amended by Public Law 116-9 in March of 2019 and directs the Department of the Interior, US Army Corps of Engineers and US Department of Agriculture to manage invasive species.

Executive Order 13112, entitled Invasive Species, issued February 3, 1999; revised as Executive Order 13751, entitled Safeguarding the Nation from the Impacts of Invasive Species, issued December 5, 2016

Executive Order (EO) 13112 of February 3, 1999 (Invasive Species), called upon executive departments and agencies to take steps to prevent the introduction and spread of invasive species, and to support efforts to eradicate and control invasive species that are established. EO 13112 also created a coordinating body -- the Invasive Species Council, also referred to as the National Invasive Species Council -- to oversee implementation of that order, encourage proactive planning and action, develop recommendations for international cooperation, and take other steps to improve the Federal response to invasive species. Past efforts at preventing, eradicating, and controlling invasive species demonstrated that collaboration across Federal, State, local, tribal, and territorial governments; stakeholders; and the private sector is critical to minimizing the spread of invasive species and that coordinated action is necessary to protect the assets and security of the United States.

EO 13751 amends EO 13112 and directs actions to continue coordinated Federal prevention and control efforts related to invasive species. This order maintains the National Invasive Species Council (Council) and the Invasive Species Advisory Committee; expands the membership of the Council; clarifies the operations of the Council; incorporates considerations of human and environmental health, climate change, technological innovation, and other emerging priorities into Federal efforts to address invasive species; and strengthens coordinated, cost-efficient Federal action.

Other Regulations that may impact IPM or Invasive Species Management

Below is a summary of other regulations that practitioners need to consider when undertaking IPM/Invasive Species Management.

Plant Protection Act of 2000 (PPA)

Amends the Federal Noxious Weed Act of 1974 (except section 1 and 15), and, in part, regulates: "the detection, control, eradication, suppression, prevention, or retardation of the spread of plant pests or noxious weeds is necessary for the protection of the agriculture, environment, and economy of the United States" and

"the unregulated movement of plant pests, noxious weeds, plants, certain biological control organisms, plant products, and articles capable of harboring plant pests or noxious weeds could present an unacceptable risk of introducing or spreading plant pests or noxious weeds. . ."

Migratory Bird Treaty Act of 1918 (MBTA)

The MBTA implements various international treaties and conventions between the United States, Canada, Japan, Mexico, and the former Soviet Union for the protection of migratory birds. Unless permitted by regulation, the MBTA provides that it is unlawful to pursue, hunt, take, capture, or kill; attempt to take, capture, or kill; possess, offer to sell, barter, purchase, deliver, or cause to be shipped, exported, imported, transported, carried, or received any migratory bird, part, nest, egg or product, manufactured or not. Criminal penalties are provided in the MBTA for violations.

National Environmental Policy Act of 1969, as amended (NEPA)

The National Environmental Policy Act requires Federal agencies to consider the potential for significant impacts to the human and natural environment by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions.

Endangered Species Act of 1973, as amended (ESA)

The ESA provides for the conservation of threatened and endangered plants and animals and the habitats in which they are found. A major provision of the ESA requires Federal agencies to ensure that any action authorized, funded, or carried out by agencies is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat. Under the ESA, EPA's decision to register a pesticide is based, in part, on the assessment of adverse effects on federally listed species and critical habitat.

Clean Water Act of 1972, as amended (CWA)

The CWA provides protections designed to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." A major provision of the CWA is a requirement for National Pollutant Discharge Elimination System (NPDES) permitting that may be required for aquatic pesticide application under certain conditions.

Comprehensive Environmental Response Compensation and Liability Act of 1980, as amended (CERCLA)

The CERCLA regulates methods of cleaning up recent and past spills of hazardous substances, defines time period within which EPA and other agencies must be notified of current spills of hazardous substances, uses reportable quantities of hazardous substances to decide when Federal and State agencies are notified of spills, and specifies Federal Natural Resource Trustees.

Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA)

The EPCRA sets up emergency response commissions and local emergency planning committees, requires industrial facilities to provide written plans to describe what they would do in the event of a "chemical emergency," requires an annual inventory of all chemicals onsite when certain amounts are exceeded, and must provide the State emergency response commissions, local emergency planning, and the local fire department with names and quantities of hazardous substances stored.

Occupational and Safety Heath Act of 1970, as amended (OSHA)

The OSHA addresses worker safety and health.

Hazardous Materials Transportation Act of 1975, as amended (HMTA)

The HMTA requires placards and shipping manifests for transporting certain quantities of hazardous materials (including pesticides), reporting of transportation accidents involving hazardous materials, and training of commercial drivers and workers who unload hazardous materials.

Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA)

This act establishes a broad new Federal program to prevent introduction of, and to control the spread of, introduced aquatic nuisance species. Establishes the Aquatic Nuisance Species Task Force.

Applicable State Pesticide Requirements

Reclamation will comply with all State pesticide laws and regulations to the maximum extent practicable, including, but not limited to: pesticide applicator certification, applicator record keeping requirements, pesticide spill and disposal requirements, bulk storage of pesticides, and notification requirements.

Department of Interior (DOI) and Reclamation Policies

Departmental Manual (DM)

The DM is the authorized means of documenting and issuing instructions, policies, and procedures that have general and continuing applicability to DOI activities, or that are important to the management DOI. The DM describes the organizations and functions of DOI's bureaus and offices, documents delegations of the Secretary of the Interior's (Secretary) authority, and prescribes the policies and general procedures for administrative activities and specific program operations. It is used to communicate the instructions of the Office of the Secretary throughout Interior, to provide guidance to the bureaus and offices in

their administrative and program operations, and to serve as the primary source of information on organization structure, authority to function, and policy and general procedures. Bureaus and offices must comply with the provisions of the DM, except to the extent that the provisions are superseded by appropriate authority (e.g., a change in statute, regulation, or Executive order; a Secretary's Order; a court decision; etc.).

DM 517 DM 1. To provide policy and requirements for DOI bureaus and offices to incorporate IPM into their pest management activities.

DM 524 DM 1. Directs bureaus/offices to prevent the introduction, establishment, and spread of invasive species, as well as eradicate and control populations of invasive species that are established. It applies to all bureaus/offices and all plants, animals, pathogens, and other organisms in terrestrial and aquatic habitats. It provides a comprehensive Departmental policy for managing invasive species on lands, waters, and facilities under the jurisdiction of the DOI. It replaces 609 DM 1, Weed Control Program.

Reclamation Manual (RM)

The RM consists of a series of Policies, Directives and Standards, and Delegations of Authority. Collectively, these assign program responsibility and authority, and document Reclamation-wide methods of doing business. All requirements in the Reclamation Manual are mandatory and constitute official Reclamation policy. The Reclamation Manual also serves as a link to Reclamation's supplements to DOI and government-wide regulations, such as the Federal Acquisition Regulations.

Policy statements reflect leadership direction and principles of Reclamation's top management, establish goals and objectives for Reclamation-wide programs and support activities, and define the broad framework in which program accomplishment will occur. They contain clear and concise statements of authority, responsibility, and accountability of line managers in carrying out the policy. Policies are structured to encourage line managers to use innovation and discretion in work accomplishment. Policies are signed by the Commissioner.

Directives and Standards contain the minimum scope and level of detail necessary to ensure that they are consistently applied by line managers. These mandatory directives and standards are instructional in nature without undue constraint in interpretation and applicability. They contain the flexibility necessary to encourage line managers to use innovative techniques or approaches. Cross references to related policy, directives and standards, and mandatory handbooks are included. Directives and standards are signed by the senior executive of the program function, unless further delegated.

Currently one policy and three directives and standards statements provide the framework for Reclamation's IPM/ Invasive Species program. These documents

are undergoing revisions and changes to these documents may not be fully incorporated into this section. Please reference the most current versions at: www.usbr.gov/recman/

RM ENV P02 *Policy, Pest Management*. Reclamation is responsible for the identification and proper management of pests on Reclamation lands and at Reclamation-owned facilities in accordance with the national policies set out in FIFRA, Carlson-Foley Act, and FWCA. This responsibility is to be fully considered in the development of an IPM/Invasive Species Program.

RM ENV 01-01 *Pest Management/Resource Protection (Integrated Pest Management) Program*. Provides information for Reclamation personnel involved with the implementation of Pest Management/Resource Protection (PM/RP) plans for the operation and maintenance of Reclamation lands and facilities.

RM ENV 01-02 *Public Notification of Aerial Pesticide Applications on Lands Managed Directly by Reclamation*. Provides information for Reclamation personnel involved in aerial applications of pesticides on lands managed directly by Reclamation.

RM PEC 10-29 *Reclamation Standard Water-Related Contract Articles, Article 29: Pest Managemen*t. This article requires contractors to effectively control undesirable plants and animals on Federal project lands, project waters, and project works for which they have operation and maintenance responsibilities.

Regulatory Considerations Specific to Pesticides

Clean Water Act and National Pollutant Discharge Elimination System (NPDES)

Application of pesticide chemicals to or over the waters of the United States are subject to compliance with the CWA. To discharge pollutants without violating the CWA Section 301 prohibition users must obtain authorization under a Section 402 NPDES permit.

The agency that issues a NPDES permit for discharges from pesticide applications depends on the location of those applications. In most cases, the state environmental protection regulatory agency (e.g., the Department of Environmental Quality or Department of Natural Resources) is the NPDES permitting authority and issues the NPDES permits for activities in their state. The Environmental Protection Agency (EPA) issues the Pesticide General Permit (PGP) only for areas and activities where the states are not authorized. Contact the appropriate authority for the process of obtaining an NPDES permit for your location and pesticide application as appropriate.

ESA Compliance

When EPA determines that pesticide use limitations are necessary to ensure that legal use of a pesticide will not harm listed species or their critical habitat, EPA may seek to change the terms of the pesticide registration to establish either generic or geographically specific pesticide use limitations. When geographically specific use limitations are necessary, bulletins are developed to put the necessary mitigations into place. These mitigations are specific to the area(s) where the species is exposed to the pesticide(s) in question.

Pesticide labels will refer the pesticide user to the *Bulletins Live! Two* website. Once the pesticide product label refers to *Bulletins*, pesticide users may check *Bulletins Live! Two* for *Bulletin* availability up to six months before applying a pesticide. Read the pesticide label prior to any application to ensure that you are aware of any *Bulletins* that may apply.

Pesticide users who fail to follow label provisions or *Bulletins* applicable to their pesticide application, whether that failure results in harm to a listed species or not, will be subject to enforcement under the misuse provisions of FIFRA section 12(a)(2)(G). Unauthorized take of listed species will subject the user to enforcement under the ESA.

Certified Pesticide Applicator Training and Standard

Pesticide applicator training, testing, and certification are operated by States and through EPA-approved Federal agency programs

Federal law requires any person who applies or supervises the use of restricted use pesticides (RUPs) to be certified in accordance with EPA regulations and state, territorial and tribal laws.

State, territorial, and tribal authorities certify applicators. You must be certified in each state, territory, and area of Indian country where you make RUP applications. Check to see if they have requirements that are stricter than the federal requirements. For example, many states require all commercial applicators, not only those using RUPs, to be certified.

If you are going to apply RUPs in a state or territory, contact the certifying agency for the requirements. Contact the Pesticide Safety Education Program (typically through the State Department of Agriculture or Natural Resources) in your state for information on training and study materials. Additionally, in Indian country, get information about how to get certified on applying RUP's by reviewing the EPA website: www.epa.gov/pesticide-applicator-certification-indian-country

EPA has finalized a set of stronger standards for people who apply RUPs. These standards enhance applicator competency standards to ensure that RUPs are used safely; establish a nation-wide minimum age for certified applicators and persons

working under their direct supervision; establish a maximum recertification interval of five (5) years for commercial and private applicators; require specialized certifications for people using specific application methods (fumigation and aerial); provide expanded options for establishing certification programs in Indian Country that acknowledge tribal sovereignty; establish protection for noncertified applicators by requiring training before they can use RUPs (under the direct supervision of a certified applicator) and clarifies and streamlines requirements for states, tribes, and federal agencies to administer their own certification programs. Any state or tribal program must comply with these standards.

8. ATTACHMENTS

Other IPM resources

Aquatic Ecosystem Restoration Foundation (AERF). (2014). Biology and Control of Aquatic Plants: A Best Management Practices Handbook. www.aquatics.org/bmp.html

EPA. 2016. Integrated Pest Management (IPM) Principles. www.epa.gov/safepestcontrol/integrated-pest-management-ipm-principles

Reclamation, 2017 (Animals). Canal Operation and Maintenance: Animals. Produced by Reclamation in collaboration with the Office of Policy and Technical Services Center, Denver Colorado. https://www.usbr.gov/assetmanagement/docs/Canal_Animals.pdf

Reclamation, 2017 (Vegetation). Canal Operation and Maintenance: Animals. Produced by Reclamation in collaboration with the Office of Policy and Technical Services Center, Denver Colorado. https://www.usbr.gov/assetmanagement/docs/Canal_Vegetation.pdf

Washington State Department of Agriculture, 2013. Integrated Pest Management Plan for Freshwater Emergent Noxious and Quarantine Listed Weeds. sccd.org/wp-content/uploads/2015/07/Integrated-Pest-Management-Plan-for-Freshwater-Emergent-Noxious-and-Quarantine-Listed-Weeds.pdf

Managing Reclamation Facilities www.usbr.gov/mussels/docs/MusselManagementOptions.pdf

Inspection and decontamination methods: Uniform and Minimum Protocols and Standards (UMPS) www.westernais.org/.

Acronyms and Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AHB	Africanized Honey Bee
AI	Active Ingredient
ANZI	American National Standards Institute
APHIS	Animal and Plant Health Inspection Service
B.t.i.	Bacillus thuringiensis israelensis
BCF	Bio-concentration factor
CAS	Chemical Abstracts Service
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
DM	Department Manual
DOI	Department of the Interior
DOT	Department of Transportation
EO	Executive Order
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESA	Endangered Species Act
FIFRA	Federal Insecticide Fungicide and Rodenticide Act
FWCA	Fish and Wildlife Coordination Act
GHS	Globally Harmonized System
GPS	Global Positioning System
HAB	Harmful Algal Bloom
HAZWOPER	Hazardous Waste Operations and Emergency Response
HMTA	Hazardous Materials Transportation Act
IARC	International Agency for Research on Cancer
IPM	Integrated Pest Management
JHA	Job Hazard Analysis
LD50	Lethal Dose to 50% of the population
MARPOL	Maritime Pollution
MBTA	Migratory Bird Treaty Act
NEPA	National Environmental Protection Act
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NTIS	National Technical Information Service
NTP	National Toxicology Program
NZMS	New Zealand Mud Snail
O&M	Operations and maintenance
OSHA	Occupational Safety and Health Administration
PELs	Permissible Exposure Limits

Acronyms and Abbreviations (continued)

PGP	Pesticide General Permit
PPA	Plant Protection Act
PPE	Personal Protective Equipment
RM	Reclamation Manual
RUP	Restricted Use Pesticides
SARA	Superfund Amendments and Reauthorization Act
SCBA	Self-Contained Breathing Apparatus
SDS	Safety Data Sheets
SMIS	Safety Management Information System
TLVs	Threshold Limit Values
TSDF	Treatment Storage or Disposal Facilities
UMPS	Uniform and Minimum Protocols and Standards
UN	United Nations
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
WID	Watercraft Inspection and Decontamination
WNV	West Nile Virus