THE ROLE OF VEGETATION IN AN INTEGRATED PEST MANAGEMENT APPROACH TO LEVEE MANAGEMENT[1]

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Abstract.--Encouraging appropriate vegetation complexes on levee slopes maximizes levee safety, and improves wildlife habitat, recreational opportunities, and aesthetic amenities. This contrasts with standard levee maintenance practices which annually destroy vegetation on levees, thereby exacerbating a series of maintenance problems, and reducing environmental quality.

INTRODUCTION

Thousands of miles of levee systems border California's major riparian zones. Though constructed from engineered fill soils and designed to restrict floodwaters to designated channels, these levees nonetheless offer opportunities to protect and enhance the state's riparian ecosystems (Davis et al. 1967).

The extensive soil area represented by the levee system supports a considerable biomass of vegetation which in turn serves as potential harborage and food sources for many riparian wildlife species (Sands 1977). In addition, many levee reaches serve as buffers, separating waterside berms bearing remnant strands of riparian vegetation from landside agricultural and urban development. See figure 1 for illustrations of various levee configurations.

Standard levee maintenance practices, however, generally assume vegetation on levee slopes is a hindrance to the prime purpose of levees, namely flood protection (US Army Corps of Engineers 1955). Under such practices, vegetation is removed each year to permit inspection of the levee surface. This practice of yearly vegetation removal and frequent soil disturbance creates and aggravates a series of levee maintenance problems ranging from erosion to ground squirrels. These maintenance practices also severely limit the opportunity to utilize levees for such secondary functions as wildlife habitat,

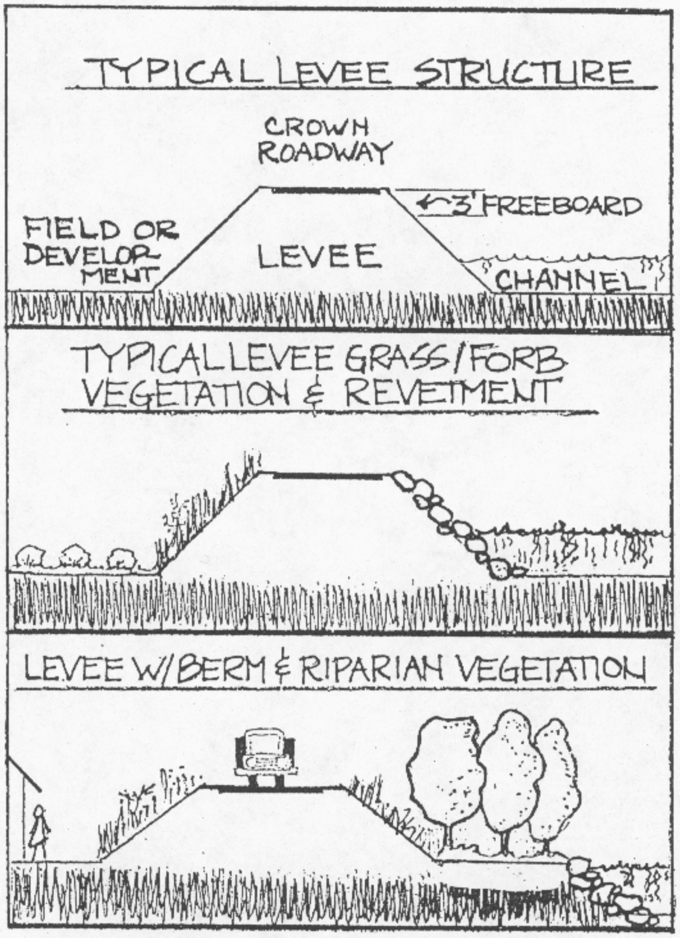

Figure 1.--Several possible levee and levee/berm configurations and their associated vegetations.

riparian vegetation enclaves, and aesthetic and recreational amenities.

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This paper describes a vegetation management program for the levee system which not only has the potential for enhancing levee safety and improving maintenance cost-effectiveness, but which affords opportunities to bring levee maintenance practices more in line with needs to improve environmental quality and protect our dwindling riparian resources.

This approach to vegetation management has been a focus of the Integrated Pest Management (IPM) program under development for the Department of Water Resources (DWR) for the past four years by the Center for the Integration of Applied Sciences (CIAS), a division of JMI, Inc. IPM is a decision-making process for analyzing and solving pest problems and features mixes of tactics and strategies compatible with environmental quality.

Utilizing the IPM approach to problem solving, CIAS staff discovered a relationship between traditional levee maintenance practices and the onset and increase of weed and rodent pests, considered major problems by DWR.

TRADITIONAL LEVEE MAINTENANCE

The cornerstone of traditional levee maintenance practices is the mandate to remove levee vegetation annually in order to inspect levee slopes (ibid.). Inspections are designed to detect damage, such as cracks, slumps, seeps, erosion, or rodent burrows, which could weaken levees during periods of high water.

The major methods utilized in levee vegetation removal include burning, surface dragging, mowing, and applying herbicide. (Brush removal in channels to improve channel capacity is another major maintenance activity, but discussion of that topic is beyond the scope of this paper.)

The dominant role vegetation removal plays in levee maintenance is illustrated by budget figures compiled for the 523 km. (325 mi.) of levees and 24,300 ha. (60,000 ac.) of channels maintained by DWR Sacramento and Sutter Maintenance Yards. As detailed in figure 2, activities associated with vegetation removal consumed 57% of the 94,000 labor hours involved in maintenance in 1978. Activities included brush cutting (27,848 hours), spraying (14,315 hours), mowing (5,164 hours), burning (3,542 hours), fire guarding (1,872 hours), and tree management (582 hours). (Environmental costs due to pesticide residues in water, air pollution from burning, loss of wildlife habitat, and reduced recreational and aesthetic values are not available.)

Consequences to the Levee Plant Community of Vegetation Removal

One of the major effects of annual vegetation removal appears to be a shift in the species of plants growing on the levees. Plant ecology

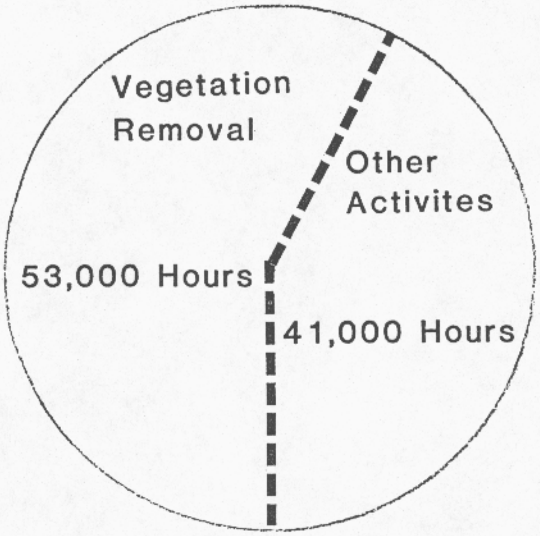

Figure 2.--DWR labor hours involved in vegetation removal, 1977-78 (total maintenance budget $2.6 million.)

literature (Weaver and Clements 1938; Frenkel 1977) indicates that systematic yearly soil disturbance creates conditions favoring broad-leaf species over grasses.

Baseline vegetation transects in five levee study areas (Daar et al. 1979) showed that broad-leaf plant represented 76% of the total species present, although two annual grasses (Avena fatua and Bromis rigidis) sometimes dominated the stands. The competitive advantage which yearly soil disturbance accords broad-leaved species may explain the presence of dense stands of thistles and other weeds such as puncture vine (Tribulus terrestris) and field bindweed (Convolvulus arvensis) which are considered undesirable on levees because they are more difficult to remove than grasses.

Once established, these "weedy" species often maintain their presence and density over many years. Herbicides are applied to these broad-leaf plants (as well as to unwanted grasses such as Johnson grass [Sorghum halopensis]) to increase broad-leaf susceptibility to the annual burning and mowing operations. Table 1 shows the amount of herbicide (active ingredient) applied in 1979 and 1980, as well as projected use in 1981. The relationship of soil disturbance to presence of broad-leaf species indicates a cycle of maintenance practices which may be requiring an ever-increasing rate of herbicide use.

Routine use of herbicides on levee vegetation also promotes a shift in plant species composition--often in a direction not desired. For example, in many locations yearly application of triazine herbicides to levee crown roadways has

Table 1.--Herbicides used on levee and channel vegetation by Sacramento and Sutter Maintenance Yards, DWR (DWR Pesticide Use Plans 1980, 1981).

	1978-79 (actual)	1979-80* (actual)	1980-81 (proposed)
Pounds	2085	916	2900
Gallons	2564	1459	4402

*Amount of herbicide use was unusually low due to managerial reorganization as well as low rainfall which inhibited use of pre-emergents.

suppressed the relatively preferred wild oat (*Avena fatua*) which formerly populated the top of the levee slope. Removal of the wild oat has allowed establishment of perennial weed species such as Bermuda grass (*Cynodon dactylon*) and field bindweed, which are less susceptible to the herbicides (Frenkel 1977). Field bindweed is an important agricultural pest, and Bermuda grass encroaching on crown roadways is considered a major pest by levee maintenance personnel who feel it interferes with grading practices necessary to keep crown roadways clear and passable during the winter.

Relationship of Vegetation Removal to Presence of Erosion, Slumps, and Cracks in Levees

Most vegetation removal on levee slopes occurs during the summer and early fall, leaving levee surfaces relatively bare until germination of winter seedlings with the first rains. In areas treated with herbicides, soil sterilants may keep sections of slope bare for several seasons.

The ability of levee slopes to resist the erosive forces of wind and water is severely reduced in the absence of a densely rooted stand of vegetation (Enlow and Musgrave 1938). This is particularly true on the waterside slope where rainfall, wave wash, scouring, and other hydraulic forces place erosive pressure on levees.

The absence of vegetation on slopes during the heat of the summer may also exacerbate the development of cracks in the levee structure. Vegetation contributes to the even drying of soils after saturation by winter flows (Mathews and Cole 1938; Satterlund 1972). Removal of vegetation may alter that process, resulting in differential soil settling and drying, which can cause cracks.

GROUND SQUIRRELS AND LEVEE VEGETATION

Vegetation removal activities of levee maintenance cause changes in the plant composition and structure on the levees. These activities also have a major impact on ground squirrels, the most important animal pest on levees.

Ground squirrels can be significant pests on levees due to the extensive network of underground burrows these animals create. Their channeling may weaken levee structure during floods and increase the likelihood of a levee break. The population biology and behavior of rodents make them good candidates for control through habitat modification (Davis 1972), and ground squirrels may be susceptible to this strategy.

The relationship of ground squirrel population density to the degree of soil disturbance has long been noted. For example, Linsdale (1946) observed that ground squirrel numbers rose and fell with the extent of overgrazing on pasture lands. High squirrel populations are characteristically associated wih barren ground, outcrops, or elevated areas (Owings and Borchert 1975), and nearby food sources. Lack of vegetation permits high visibility for the squirrels, which aids in social communication and predator detection (Owings 1977). With the construction of levees and the traditional maintenance practices associated with them, people have inadvertently created prime ground squirrel habitat which is lacking only an enriched food source, often supplied by adjacent agriculture.

Figure 3 shows the results of a detailed study on a section of levee which demonstrated the relationship of ground squirrel density to vegetation and other environmental features. The number of burrows is indicative of the population size of squirrels and is a direct indication of the damage to levees caused by the squirrels.

Squirrel burrows on a 3.2-km. (2-mi.) stretch of levee encompassing various environments were counted in the late summer of 1980, after the levee had been burned. The squirrels' particular attraction to areas of barren ground was demonstrated by the high burrow densities observed in the area where overgrazed pasture extended up onto the side of the levee. Burrow numbers on the levee dropped where the fence line ended.

A second strong determinant of ground squirrel distribution is availability of food sources. Exceptionally high burrow densities were present near the walnut orchard. The area immediately adjacent to the walnut orchard, which had 583 holes per km. (932 per mi.), had been fumigated earlier in the season, so counts may actually have been depressed there. Areas within the squirrel foraging range of the walnuts on both sides of the levee also had very high burrow counts. (It was impossible to count burrows in the area of stone revetment on the water side opposite the orchard, although squirrel densities were clearly high there. The high counts in areas near the orchard showed the enhanced effect on squirrel densities produced by both disturbed slopes and nearby food.)

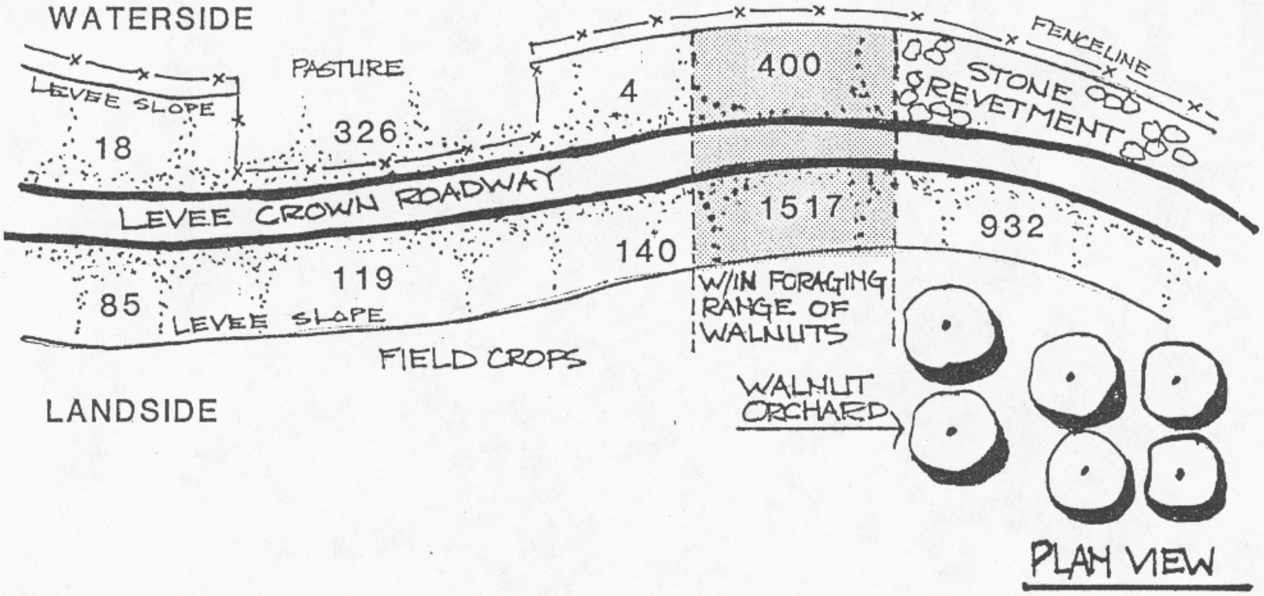

Figure 3.--Distribution of ground squirrels on 3.2 km. (2 mi.) of levee at East Yolo Bypass, Yolo County, California, August, 1980. Counts are in number of burrows per levee mile. Before burning, yellow star thistle (Centaurea solstitialis) and wild oat (Avena fatua) comprised the dominant vegetation on much of the otherwise undistinguished levee slope. The linear distance along the levee is not drawn to scale.

Areas lacking both nearby walnuts and the disturbed surface of the overgrazed pasture had lower burrow counts. In these areas, a weaker propensity of squirrels to burrow on land- versus water-side slopes may have been demonstrated. That is, there is a propensity to burrow on land-side slopes, but that propensity is less pronounced in areas which are away from orchards and overgrazed pastures.

Vegetation on levee slopes during the summer and fall may be particularly important in habitat management of ground squirrels. During this period, young, first-year animals are actively dispersing, seeking new area in which to settle (Dobson 1979). Slopes covered with vegetation at this time of the year will be much less attractive to migrating squirrels than those freshly denuded by annual vegetation removal practices.

The traditional approach of annually burning levee slopes followed by dragging to obliterate burrow openings and smooth the levee surface improves the quality of ground squirrel habitat. In contrast, a program of deliberately maintaining certain vegetation on levee slopes may tend to discourage squirrel colonization. The tactic of revegetating levee slopes with appropriate plant species should be integrated into an active squirrel control program if permanent population reduction is to occur.

AN INTEGRATED PEST MANAGEMENT APPROACH TO LEVEE VEGETATION

An IPM approach to vegetation management offers a way out of the traditional dilemma of levee maintenance practices which exacerbate weed and rodent pests. Furthermore, this method shows promise as a means of achieving the objectives of maximum levee safety while simultaneously improving environmental quality of riparian areas.

Traditional approaches to levee maintenance have a single objective--that of flood safety. In contrast, the IPM approach recognizes flood safety as the primary maintenance objective but places high value on other goals including improvement of wildlife habitat and recreational opportunities, enhanced aesthetics, and reduced pesticide use. At the level of implementation, the main points at which the approaches differ are in the way in which vegetation is viewed and the process by which maintenance decisions are made.

Despite the wide variation in biotic and abiotic conditions of various levee reaches, traditional maintenance practices have tended to give all levee reaches equal attention and treatment. Thus, a uniform policy of slope clearing to facilitate inspection is implemented irrespective of characteristics of the levee vegetation. By contrast, the IPM approach gives more recognition to the uniqueness of each levee stretch in the belief that improved practices can be developed which both maximize flood safety and improve environmental quality.

When reduced to their basic structural forms, levees can be defined as "fill slopes." When viewed in this manner, both engineering (US Army Corps of Engineers 1978) and biological (Lines *et al*. 1978) expertise would agree that vegetation can and does play a key role in stabilizing these slopes against the erosive forces of wind, water, temperature fluctuation, and damage by animals, humans, or vehicles.

Damage to levees due to erosion, cracking, slumping, seeps, etc., may originate in soil type, construction techniques, seismic action, burrowing rodents, water pressure, maintenance practices, or other forces. Whatever the origin of the problem, the presence of vegetation holding the soil mass together can help reduce (and in some cases, prevent) the onset or impact of such problems.

Thus, protection and encouragement of certain vegetation-types on levee slopes can be seen as an important tool in maximizing the structural integrity--and therefore the safety--of these structures. Should a conflict appear to arise between the presence of vegetation and the need to inspect the levees, a site-intensive levee monitoring program offers a solution (fig. 4).

Under an IPM vegetation management system, information on current site or pest conditions is integrated with historical data on the construction and maintenance history of a levee reach. Site conditions are evaluated through use of a variety of monitoring techniques and record-keeping systems which vary in intensity, depending on a priority assigned to a given site. Utilizing the monitoring data, injury and action levels are established for the vegetation, and selective treatments are chosen. Spot treatments, selected from mechanical, cultural, biological, or chemical controls, are timed to minimize side effects on non-target organisms. Strategies and tactics are evaluated for long-term effectiveness and cost.

Utilizing this system, the maintenance manager has greater flexibility when it comes to the apparent conflict between vegetation and inspection of levees. By prioritizing sites to be monitored, those with no significant history of maintenance or other problems can receive a less intense level of monitoring, freeing maintenance personnel to focus major monitoring attention on areas with chronic flood history or maintenance problems. (This situation may occur *de facto* under the traditional approach but is not recorded, planned, or approached in a systematic manner.)

Ideally, levee inspections occur just before, during, and just after flood season (i.e., November-March each year). Under the IPM system, spring inspections (which detect damage from win-

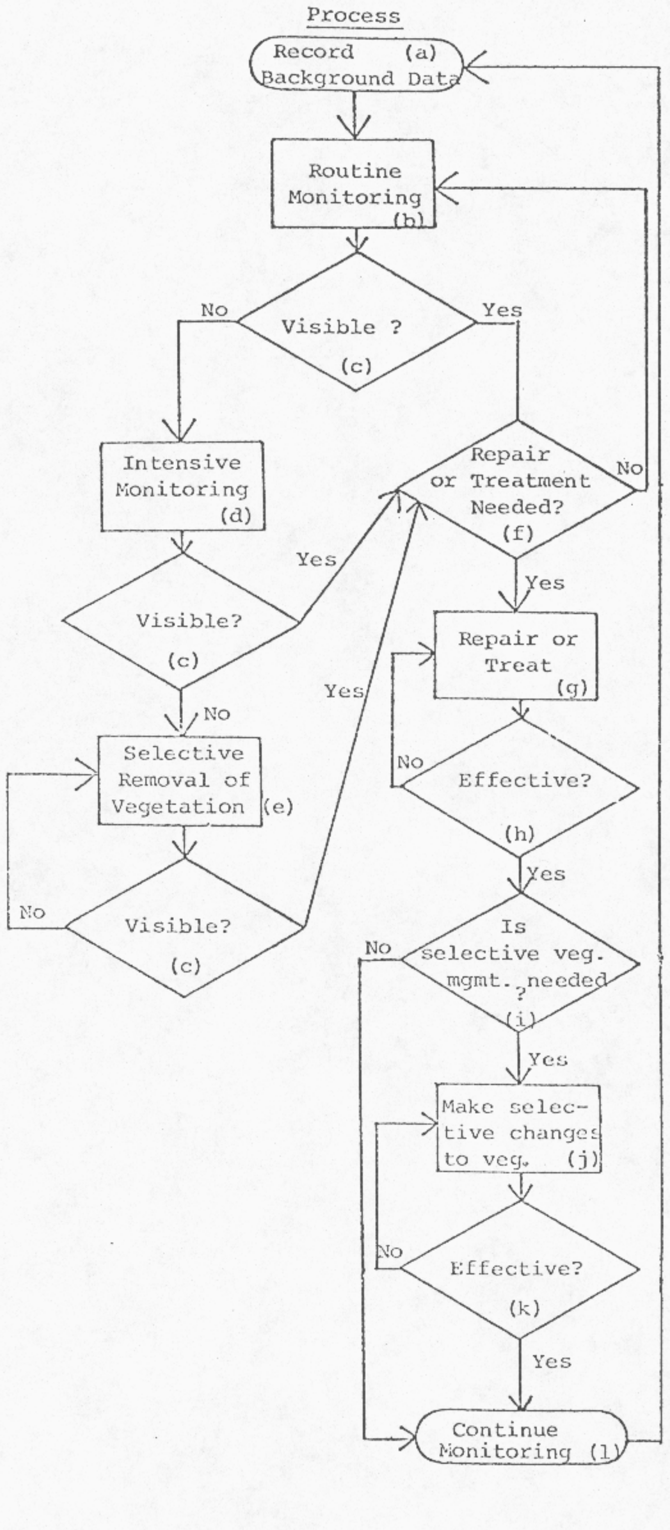

Figure 4.--Diagram showing a levee slope monitoring process. Key variable is slope visibility.

ter flows) should be timed to occur before spring grasses have grown more than one foot tall. By shifting existing maintenance personnel to inspection/monitoring roles in early spring, it should be possible to thoroughly monitor most sections of levee prior to dense growth of vegetation. If vegetative growth becomes too dense to detect potential levee damage, selective removal of that vegetation can occur. If damage is found, repairs can be made. If warranted, the vegetation at that site could be removed periodically, or vegetation more suited to the inspection and maintenance needs at that site could be encouraged.

Encouraging Appropriate Vegetation on Levees

A major strategy in an IPM program for levees is the development of practices which select for and encourage certain existing grass species and low-growing broad-leafed plants which reinforce the structural integrity of levees by reducing erosion and ground squirrel habitat. Examples of candidate species include salt grass (*Distichlis spicata*); creeping ryegrass (*Elymus triticoides*); perla grass (*Phalaris tuberosa* 'Hurtiglumis') and saltbush (*Atriplex* spp.).

Under some circumstances it may be appropriate to introduce new species to the levees (Daar *et al*. 1979), particularly in areas adjacent to residential subdivisions, where concerns about the relation of levee management to fire danger, recreation, and aesthetics are the focus of attention. Five candidate species for replacement vegetation in urban areas are showing promise as relatively low-growing, dense, low-maintenance slope covers in test plots at two levee locations near Sacramento. These species include: sageleaf rockrose (*Cistus salvifolius*), Cleveland sage (*Salvia clevelandii*), Australian saltbush (*Atriplex semibaccata*), dwarf coyote brush (*Baccharis pilularis* 'Twin Peaks No. 2'), and Noel grevillia (*Grevillia noellii*).

Benefits of IPM Vegetation Management

The benefits of a selective vegetation-management system will be most evident during the flood season. The condition of levees at any given site will be known in intimate detail due to the data recorded by the monitoring program. This results in greater predictability of a given levee reach when under flood stress. At sites with chronic maintenance problems or flood histories, vegetation on the land side of the levee (the side visible during high water) will have been selectively managed to retain its rootmass while restricting its height, thus maximizing the stability of the slope as well as its visibility in case of a flood fight. Decisions regarding setting of priories and scheduling work, deployment of labor and materials, and evaluation of efficacy of maintenance efforts will be aided by the data collected by the monitoring process.

Other benefits of particular relevance to the riparian system would include reduction in the use of pesticides, more extensive wildlife habitat, enhanced recreational opportunities, and an increase in the aesthetic quality of the levee environment.

In conclusion, an IPM approach to managing levee vegetation shows promise as a method for achieving the dual objectives of maximum levee safety and improved environmental quality.

In recognition of this potential, the DWR is moving to implement new IPM practices including more intensive levee-monitoring and record-keeping systems, development of injury- and action-level concepts, and use of selective vegetation-management techniques to encourage the presence of certain grasses and other vegetation compatible with multiple-use management objectives. It is hoped that these and other IPM practices will become adopted Department-wide and serve as a model for the state's 7,000 local water districts, whose activities have a profound impact on California's dwindling riparian resources.

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