Rough Acres Ranch

Notice of Preparation / Initial Study

Comment Letter #7

Attorney for Donna Tisdale

Erin Crouthers

From: Bennett, Jim [Jim.Bennett@sdcounty.ca.gov]
Sent: Monday, May 19, 2014 8:03 AM
To: Erin Crouthers
Cc: Campbell, Dennis
Subject: FW: Scoping Comments of Backcountry Against Dumps and Donna Tisdale for the Rough Acres Ranch Campground/Retreat Center Project DEIR (Email 2 of 2)
Attachments: Backcountry's Scoping Comments for the Rough Acres Ranch Project DEIR.pdf; Exhibit 4 to Backcountry's Rough Acres Ranch DEIR Scoping Comments.pdf; Exhibit 5 to Backcountry's Rough Acres Ranch DEIR Scoping Comments.pdf; Exhibit 6 to Backcountry's Rough Acres Ranch DEIR Scoping Comments.pdf; Exhibit 7 to Backcountry's Rough Acres Ranch DEIR Scoping Comments.pdf

More comments

Jim Bennett, P.G. #7707, CHG#854
Groundwater Geologist

County of San Diego
Planning & Development Services
5510 Overland Avenue, Suite 110, San Diego, CA 92123
Phone: 858-694-3820 Fax: 858-694-3373

From: Jamey Volker [mailto:jvolker@volkerlaw.com]
Sent: Friday, May 16, 2014 6:14 PM
To: Bennett, Jim
Cc: 'Stephan Volker'
Subject: Scoping Comments of Backcountry Against Dumps and Donna Tisdale for the Rough Acres Ranch Campground/Retreat Center Project DEIR (Email 2 of 2)

Dear Mr. Bennett,

Attached to this second of two emails please the Scoping Comments of Backcountry Against Dumps and Donna Tisdale on the Rough Acres Ranch Project, SCH No. 2014041042, and Exhibits 4-7 to the Scoping Comments. Due to their size, I just sent you Exhibits 1-3 to the Scoping Comments in a separate email. Note that I inadvertently omitted the Scoping Comments themselves from my first email, so they are attached to this email.

We have also FedExed you today a full copy of the Scoping Comments and all seven exhibits.

Please make our Scoping Comments a part of San Diego County's public record for its review of the Project and associated development of an EIR.

Please confirm that you have received the Scoping Comments and exhibits and are able to open all the attached files. Should you have any difficulty in opening the attached Scoping Comments and exhibits, please contact me via email or at the telephone number listed below.

Best regards,

Jamey Volker
Attorney for Backcountry Against Dumps and
Donna Tisdale

Jamey M.B. Volker

Law Offices of Stephan C. Volker
436 - 14th Street, Suite 1300
Oakland, CA 94612
Tel: (510) 496-0600
Fax: (510) 496-1366
jvolker@volkerlaw.com

Erin Crouthers

From: Bennett, Jim [Jim.Bennett@sdcounty.ca.gov]
Sent: Tuesday, May 20, 2014 2:26 PM
To: Erin Crouthers
Cc: Campbell, Dennis
Subject: Rough Acres Ranch - Comment Letter#7 (e-mail 1 of 3)
Attachments: Backcountry's Scoping Comments for the Rough Acres Ranch Project DEIR.pdf; Exhibit 1 to Backcountry's Rough Acres Ranch DEIR Scoping Comments.pdf; Exhibit 2 to Backcountry's Rough Acres Ranch DEIR Scoping Comments.pdf

Jim Bennett, P.G. #7707, CHG#854
Groundwater Geologist

County of San Diego
Planning & Development Services
5510 Overland Avenue, Suite 110, San Diego, CA 92123
Phone: 858-694-3820 Fax: 858-694-3373

From: Jamey Volker [mailto:jvolker@volkerlaw.com]
Sent: Saturday, May 17, 2014 5:53 PM
To: Bennett, Jim
Cc: 'Stephan Volker'
Subject: Retransmission of Backcountry's Scoping Comments for the Rough Acres Ranch Project DEIR and Exhibits 1-3 thereto (Email 1 of 2)

Dear Mr. Bennett,

I received a notification that the first of my two emails (pasted below) to you yesterday evening transmitting the Scoping Comments of Backcountry Against Dumps and Donna Tisdale on the Rough Acres Ranch Project and Exhibits 1-7 thereto did not go through due to the size of the attachments. I am therefore resending the attachments to that first email – the Scoping Comments and Exhibits 1-3 thereto – in two separate emails. This first email transmits the Scoping Comments and Exhibits 1 and 2 thereto. Exhibit 3 is transmitted in the next email.

As noted in my emails to you yesterday, we also FedExed you yesterday a full copy of the Scoping Comments and all seven exhibits.

Please make these Scoping Comments a part of San Diego County's public record for its review of the Project and associated development of an EIR.

Please confirm that you have received the Scoping Comments and exhibits and are able to open all the attached files. Should you have any difficulty in opening the attached Scoping Comments and exhibits, please contact me via email or at the telephone number listed below.

Best regards,

Jamey Volker
Attorney for Backcountry Against Dumps and
Donna Tisdale

Jamey M.B. Volker
Law Offices of Stephan C. Volker
436 - 14th Street, Suite 1300

Oakland, CA 94612
Tel: (510) 496-0600
Fax: (510) 496-1366
jvolker@volkerlaw.com

From: Jamey Volker [mailto:jvolker@volkerlaw.com]
Sent: Friday, May 16, 2014 6:08 PM
To: 'jim.bennett@sdcounty.ca.gov'
Cc: 'Stephan Volker'
Subject: Scoping Comments of Backcountry Against Dumps and Donna Tisdale for the Rough Acres Ranch Campground/Retreat Center Project DEIR

Dear Mr. Bennett,

Attached to this email please find the Scoping Comments of Backcountry Against Dumps and Donna Tisdale on the Rough Acres Ranch Project, SCH No. 2014041042. Exhibits 1-3 to the Scoping Comments are also attached to this email. Due to their size, Exhibits 4-7 to the scoping comments will be sent in a subsequent email. We have also FedExed you today a full copy of the Scoping Comments and all seven exhibits.

Please make these Scoping Comments a part of San Diego County's public record for its review of the Project and associated development of an EIR.

Please confirm that you have received the Scoping Comments and exhibits and are able to open all the attached files. Should you have any difficulty in opening the attached Scoping Comments and exhibits, please contact me via email or at the telephone number listed below.

Best regards,

Jamey Volker
Attorney for Backcountry Against Dumps and
Donna Tisdale

Jamey M.B. Volker
Law Offices of Stephan C. Volker
436 - 14th Street, Suite 1300
Oakland, CA 94612
Tel: (510) 496-0600
Fax: (510) 496-1366
jvolker@volkerlaw.com

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Stephan C. Volker
Joshua A.H. Harris (of Counsel)
Alexis E. Krieg
Stephanie L. Clarke
Daniel P. Garrett-Steinman
Jamey M.B. Volker
M. Benjamin Eichenberg
Lauren E. Pappone

Law Offices of
Stephan C. Volker
436 – 14th Street, Suite 1300
Oakland, California 94612
Tel: (510) 496-0600 ❖ Fax: (510) 496-1366
svolker@volkerlaw.com

11.185.01

May 16, 2014

Via Electronic Mail and FedEx
email: jim.bennett@sdcounty.ca.gov

Jim Bennett
Planning and Development Services
Project Processing Counter
5510 Overland Avenue
Suite 110
San Diego County, CA 92123

Re: Scoping Comments of Backcountry Against Dumps and Donna Tisdale on the Rough Acres Ranch Project, SCH No. 2014041042

Dear Mr. Bennett:

Pursuant to the California Environmental Quality Act ("CEQA"), Public Resources Code section 21000 *et seq.*, and the County's April 10, 2014 Notice of Preparation ("NOP"), Backcountry Against Dumps and Donna Tisdale (collectively, "Backcountry") submit the following scoping comments for the Draft Environmental Impact Report ("DEIR") being prepared by San Diego County ("County") for the Rough Acres Ranch Conference/Retreat, Wellness Center and Campground Facility Project ("Rough Acres Ranch Project" or "Project").[1]

The Project would involve the construction and use of 149 campsites, three houses (with adjacent storage buildings), two clubhouses, two swimming pools, a skeet shooting range, an equestrian center, a 200-person amphitheater, an archery course and an athletic field. Additionally, the Project would require construction of a new road, significant road work – including widening – on several existing un-paved roads, and substantial grading (7,500 cubic yards of balanced cut and fill). Once built, the Project would attract up to *2,600 people* at any given time. It would also maintain "10-50 cattle, 5-40 horses, and approximately *20,000* chickens." County Planning and Development Services Department, April 10, 2014, CEQA Initial Study ("Initial Study") at 28 (emphasis added).

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[1] On or about May 8, 2014, the County extended the original deadline for scoping comment submission, May 12, to May 19. Backcountry's (May 14) scoping comments are therefore timely.

With so many people, livestock, facilities and activities, the Project would – in combination with the Tule Wind project, the Soitec Solar projects (including the Rugged Solar project) and other planned regional developments – ruin the quietude, peacefulness and sense of place for the current residents and visitors in the area. It would also threaten the health and welfare of the area's residents, visitors and wildlife. And, without consideration for the ongoing statewide drought, the Project would further tax the already strained regional groundwater supplies. For these reasons and others, Backcountry opposes the Project as proposed.

In further expression of these major concerns and others, Backcountry offers the following comments to aid the County in developing the DEIR for the Project.

I. THE DEIR MUST CONTAIN AN ACCURATE PROJECT DESCRIPTION, A ROBUST ANALYSIS OF PROJECT ALTERNATIVES AND IMPACTS.

A. The DEIR Must Provide a Complete and Accurate Project Description.

The Initial Study and NOP omit or confuse many critical details about the Project that the County must provide in the DEIR. For example, it is unclear from the Initial Study how the Project site is zoned. The Initial Study states on page 36 that the "property is zoned A72 (General Agriculture)," but then on page 38 it states that the "project is zoned S92."

The DEIR must clarify the zoning on the Project site. The County must also clarify in the DEIR whether or not a stormwater management plan has been prepared and, if so, provide it as an appendix. While the Initial Study states in some places that a stormwater management plan was prepared, it fails to identify who prepared it, let alone provide it as an appendix or instruct readers as to where it can be found. Initial Study at 32 ("As outlined in the Storm Water Management Plan (SWMP) dated January 28, 2013 and prepared by ," (omission of preparer in original)). Indeed, it is unclear whether there even is such a plan. *Id*. at 33 ("A Stormwater Management Plan for Priority Projects is required . . .").

Among its numerous omissions, the Initial Study and NOP fail to identify the source of the electricity the Project would need to power the "full hookups" at the proposed campsites. Initial Study at 2. The Initial Study also fails to specify whether or not campfires would be allowed at the campsites, let alone discuss the corresponding safety risks.

B. The DEIR Should Analyze Reduced Project Alternatives.

To comply with CEQA, agencies must consider a "reasonable range" of alternatives, including a "no project" alternative, that "would avoid or substantially lessen any of the significant effects of the project." 14 Cal. Code Regs. [CEQA Guidelines ("Guidelines")] §§ 15126.6(a) (first and last quotes), (e) (second quote); *Village of Laguna Beach, Inc. v. Board of Supervisors* (1982) 134 Cal.App.3d 1022, 1028. To do so here, the County must analyze alternatives that would reduce Project usage to less than the current 2,600-person maximum, which is disproportionate to and disruptive of existing uses in the area, including residential uses, hiking, sightseeing, birdwatching, wildflower and wildlife viewing, photography and camping.

The County must also analyze alternatives that, with or without reduced Project usage, would avoid or substantially lessen specific Project impacts. For example, the County should analyze alternatives that would reduce the Project's water use, including the use of graywater systems[2] and rainwater harvesting.[3] The County should also analyze alternatives that would reduce the Project's noise, including for example, substituting an enclosed theater for the planned open-air amphitheater.

C. The DEIR Must Identify Adequate, Reasonably Certain Water Sources for the Project and Analyze the Impacts of Supplying that Water.

As the Initial Study indicates, the Project is "subject to the [San Diego County] Groundwater Ordinance" since "the project would obtain its water from groundwater sources." Initial Study at 31; Groundwater Ordinance § 67.722(B) (requiring the provision of groundwater by a "Water Service Agency" as defined in the ordinance (§ 67.703), or the preparation of a Groundwater Investigation for any project that uses "groundwater not provided by a Water Service Agency."); *see also* § 67.711. Because no water service agency has yet been identified to serve the Project, the Project "shall not be approved unless the [County] finds, based upon the Groundwater Investigation . . . that groundwater resources are adequate to meet the groundwater demands for the project." Groundwater Ordinance § 67.722(B).

CEQA similarly requires the County to identify in its DEIR the likely water sources for the Project, and analyze the "environmental impacts of exploiting those sources" and "how those impacts are to be mitigated." *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* ("*Vineyard*") (2007) 40 Cal.4th 412, 421 (quote), 434, 440-441. An EIR that neglects to explain the likely sources of water and analyze their impacts, but leaves long-term water supply considerations to later stages of the project, does not serve the purpose of sounding an environmental alarm bell." *Id.* at 441 (internal quotations and citation omitted).

Thus, the DEIR and Groundwater Investigation must identify reliable and adequate

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[2] Installation of graywater systems is governed by Chapter 16A of the California Plumbing Code (Title 24, Part 5, Chapter 16A of the California Code of Regulations).

[3] The County encourages rainwater harvesting and provides information on rain barrels on its website (http://www.sdcounty.ca.gov/dpw/watersheds/residential/rain_barrel.html). The City of San Diego has also published a Rainwater Harvesting Guide, which is available here: http://www.sandiego.gov/water/pdf/conservation/rainwaterguide.pdf

sources of groundwater, and consider the impact that water use would have on the surrounding environment. Groundwater Ordinance § 67.722(B); *Vineyard*, 40 Cal.4th at 431. As the Initial Study admits, the Project may "[s]ubstantially deplete groundwater supplies or interfere substantially with groundwater recharge." Initial Study at 31. CEQA requires an adequate and thorough analysis of these impacts in the DEIR, including an analysis of whether and how the Project would impact the Environmental Protection Agency ("EPA")-designated Campo-Cottonwood Sole Source Aquifer, which is adjacent to (and potentially underlies) the Project site. Federal Environmental Protection Agency, October 2008, Campo-Cottonwood Sole Source Aquifer Map (attached hereto as Exhibit 1).

The DEIR must also consider the cumulative impact of drawing water for this Project in addition to the other projects in the surrounding area, such as the Soitec Solar project and the Tule Wind project, both of which will require large quantities of water. Guidelines § 15130. Indeed, it must consider *all* reasonably foreseeable projects in the area and the water they will use before determining what water is available for this Project. *Id.* One potential cumulative impact of regional groundwater pumping that the DEIR must analyze is flow reduction in local springs and seeps, along with the associated desiccation of spring/seep-fed wetlands.

D. The DEIR Must Analyze the Project's Impacts on Water Quality, Hydromorphology and Erosion.

In addition to identifying the sources of water for the Project and determining the impacts of using those water sources, the DEIR must also look at the Project's impacts on water quality (both surface water and groundwater quality) and local hydromorphology. Among other things, the DEIR must analyze the impacts of construction, excavation, and operation on the existing drainage, runoff and groundwater recharge patterns on and near the Project site, as well as any cumulative impacts in conjunction with projects like Tule Wind and Soitec Solar. Guidelines § 15130.

According to the Initial Study, potentially significant impacts include: "[s]ubstantially alter[ing] the existing drainage pattern of the site;" "[c]reat[ing[or contribut[ing] runoff water which would exceed the capacity of existing storm drainage systems;" and "[p]rovid[ing] substantial additional sources of polluted runoff." Initial Study at 32-33. The DEIR must consider these impacts and any potential mitigation lessening their significance. And in analyzing the Project's generation of polluted runoff, the DEIR must consider the impacts of the lead leachate that the planned skeet shooting (from lead bullets and the skeet traps themselves) would create. *Id*. at 24; Fish & Game Code § 3004.5(a) (California's ban on using lead ammunition in hunting big game does not prohibit the use of lead ammunition at skeet shooting ranges).

By "[s]ubstantially altering the existing drainage pattern of the site," including through its extensive planned soil grading, the Project would also likely cause increased erosion, which the

DEIR must analyze. *Id*. at 32. The Initial Study concludes that erosion and siltation would be a "Less than Significant Impact" and need not be analyzed in the DEIR because the Project "will not alter any drainage patterns of the site or area on- or off-site" and would implement various mitigation measures "outlined in the Storm Water Management Plan." *Id*. at 32 (quotes), 19-20; County Planning and Development Services Department, April 10, 2014, Notice of Preparation Documentation ("NOP Documentation") at 2 ("All questions answered 'Less than Significant Impact' or 'Not Applicable' will not be analyzed further in the [EIR]"). Both rationales for ignoring Project-induced erosion in the DEIR are wrong.

First, on the *very same page* it claims that the Project would not cause significant erosion because it "will not alter any drainage patterns of the site," the Initial Study concludes to the contrary that the Project would cause a "Potentially Significant Impact" by "[s]ubstantially alter[ing] the existing drainage pattern of the site or area." *Id*.

Second, it is impermissible for the County to omit analysis in the DEIR of a potentially significant Project impact on the grounds that it would be mitigated. CEQA requires that EIRs discuss *both* the significant environmental impacts *and* measures to mitigate those impacts. Pub. Res. Code § 21002.1; Guidelines §§ 15126, 15126.2, 15126.4. It would eviscerate CEQA and contravene its basic purpose if lead agencies were allowed to forego preparing project EIRs just by alleging that all the project impacts would be mitigated. Pub. Res. Code § 21061. Furthermore, as discussed above in Section I(A), it is unclear here whether a stormwater management plan (and accompanying mitigation measures) has even been prepared here.

E. The DEIR Must Analyze Project-Generated Soil Pollution.

As just discussed, the DEIR must analyze Project-generated soil erosion, as well as the cumulative impact of erosion from all past, present and foreseeable future projects in the watershed. It is impermissible for the County to omit analysis in the DEIR of this potentially significant impact based on a conclusory assertion that it would be mitigated. Initial Study at 19; NOP Documentation at 2. CEQA requires that EIRs discuss *both* the significant environmental impacts *and* measures to mitigate those impacts. Pub. Res. Code § 21002.1; Guidelines §§ 15126, 15126.2, 15126.4.

The DEIR must also analyze how the soils in the area are adequate to support "the use of septic tanks or alternative wastewater disposal systems." Initial Study at 21. The Initial Study claims that this impact is less than significant and thus need not be discussed further in the DEIR. Initial Study at 21; NOP Documentation at 2. Not so. The Initial Study provides *no* support for its less-than-significant-impact conclusion and is internally inconsistent. Initial Study at 21. It states that because the County Department of Environmental Health ("DEH") "reviewed the [on-site wastewater systems] lay-out for the project," the project therefore "has soils capable of adequately supporting the use of septic tanks." *Id.* But this conclusion does not follow from the reasoning provided. Without an explanation of what DEH found based on its review, there is no evidence that the Project-area soils are suitable for septic tank use. Furthermore, the Regional Water Quality Control Board has clearly indicated that "it needs a CEQA document before it can make a determination" and "study is needed relating to that wastewater treatment system." *Id.* Therefore, a designation as "less than significant" in this case is improper. The DEIR must discuss the potential impacts to soil of using a septic tank and how they would be mitigated. Pub. Res. Code § 21002; Guidelines §§ 15126, 15126.2, 15126.4.

One alternative to the proposed septic systems that the County should analyze in the DEIR is using composting toilets. Composting toilet systems have been used successfully in many campground and other outdoor locations,[4] and provide a significantly more environmentally friendly – and very low-maintenance – alternative to septic systems.

F. The DEIR Must Analyze the Project's Impacts to Wildlife.

The Initial Study states that all five checklist items under the "Biological Resources" category may be "potentially significant impacts," including impacts to species, habitat, vegetation, and conflicts with other plans and laws. Initial Study at 13-15. It claims that all of these impacts will be analyzed in an DEIR and a Biological Resources Report. *Id.* However, the Initial Study provides no detail on what species may be affected, aside from a short list of plants in the area.

The DEIR must consider all of the potential species in the area, including the federally endangered Quino checkerspot butterfly ("QCB"), whose critical habitat extends near the Project site, the federally endangered Peninsular bighorn sheep ("PBS"), the federally protected golden eagle, and the burrowing owl, which is a California State Species of Special Concern.[5] The County must thoroughly analyze the Project's impacts to these and other species.

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[4] See, for example, the Phoenix composting toilet system (http://www.compostingtoilet.com/) which is currently used in numerous campground and outdoor settings, including Volcanoes National Park in Hawaii, along the American River near Auburn, California, and in Smith Rock State Park near Prineville in Oregon.

[5] The federally listed species known or believed to occur in Imperial County include those listed in the U.S. Fish and Wildlife Service's Species by County Report for San Diego County, which is available here: http://ecos.fws.gov/tess_public/countySearch!speciesByCountyReport.action?fips=06073. The state-listed species can be found on the California Department of Fish and Game's website here: http://www.dfg.ca.gov/wildlife/nongame/list.html.

1. Project Impacts to Birds

There are numerous avian species, including Golden Eagles and other raptors, that use the "[p]otential wildlife corridors [that] exist throughout project site." Initial Study at 15. Golden eagles are fully protected under federal, state and local laws, including the Migratory Bird Treaty Act ("MBTA"), 16 U.S.C. § 701, *et seq.*, and the Bald and Golden Eagle Protection Act ("Eagle Act"), 16 U.S.C. § 668, as well as state and local designations as sensitive and protected species. The County has designated golden eagles as a sensitive species (County Group I) and its CEQA biological guidelines mandate special considerations for golden eagles. County of San Diego, Land Use and Environmental Group, *Guidelines for Determining Significance and Report Format and Content Requirements: Biological Resources*, Fourth Revision, September 2010.[6]

In order to truly understand the Project's impacts on golden eagles, the DEIR must include adequate surveys of the area to determine the presence of golden eagles, other raptors, and burrowing owls in the area, in compliance with all local, state, and federal guidelines on how to adequately perform these surveys. *Berkeley Keep Jets Over the Bay Committee v. Board of Port Commissioners* ("*Berkeley Keep Jets*") (2001) 91 Cal.App.4th 1344, 1355-1356, 1370. CEQA requires that the agency "use its best efforts to find out and disclose all that it reasonably can" about the environmental consequences of the Project, including performing site-specific surveys. Guidelines § 15144; *Vineyard*, 40 Cal.4th at 428, 431; *Berkeley Keep Jets*, 91 Cal.App.4th at 1355-1356. Only once these studies are complete can the County begin to determine the Project's impacts. And once it does, it must describe those impacts in sufficient detail to allow decisionmakers and the public to make an informed decision about the Project. *Id.*

2. Project Impacts to the Quino Checkerspot Butterfly

Similarly, the DEIR must include surveys for the QCB and its host plants, in order for the public and decisionmakers to make an informed decision about the Project, as required under CEQA. *Berkeley Keep Jets,* 91 Cal.App.4th at 1355-1356. QCB are difficult to spot in many of their life stages and require trained biologists to determine their presence in the Project area. 74 Fed.Reg. 28776-28781, 28784; U.S. Fish & Wildlife Service, Recovery Plan for the QCB, August 11, 2003, pp. 6, 33-34, 87, 106 (attached hereto as Exhibit 2). QCB risk being trampled during construction and operation of the Project both by the creation of new roads and structures, and the increased human presence in the area. 67 Fed.Reg.18359; Exhibit 2 at iii-iv, 1, 5, 32-35, 55-63. QCB host plants also face these same risks, and without these host plants QCB cannot survive. *Id.* The Project's hydrologic impacts may also harm QCB host plants and subsequently, the butterflies themselves. *Id.* The DEIR must consider all these direct and indirect impacts to the QCB, as well as any host plants in the area.

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[6] Available at: www.sdcounty.ca.gov/pds/docs/Biological_Guidelines.pdf

3. Project Impacts to the Peninsular Bighorn Sheep

The DEIR must also consider the Project's impacts to PBS – a federally endangered species that has critical habitat nearby and may use the Project area as a connectivity corridor. 74 Fed.Reg. 17288-17289. As the Initial Study admits, the Project area may be especially useful for species connectivity. Initial Study at 15 ("Potential wildlife corridors areas [sic] exist throughout the project site.") Therefore, like avian species and QCB, the DEIR must include site-specific surveys to determine the presence of PBS in the area, and accurately analyze the impact of the Project on these sheep and their habitat.

4. The Project's Cumulative Biological Impacts

There are numerous other projects in the immediate vicinity of the Rough Acres Ranch Project, such as the Tule Wind project and the Soitec Solar project, and their impact on biological resources must be considered in conjunction with the impacts of this Project. Guidelines § 15130. The DEIR must discuss the combined impact to wildlife and vegetation in the area to determine (1) the impact of these projects as a whole, and (2) the effectiveness of any proposed mitigation measures when analyzed in conjunction with the impacts from other projects. *Id.* Due to the close proximity to these other developments, the impact to wildlife and vegetation could be greatly exacerbated. For example, the substantial cumulative groundwater pumping contemplated for the Rough Acres Ranch Project and other nearby projects could cause significant reductions in local spring and seep flow and, in turn, desiccate spring/seep-fed wetlands on which local wildlife currently rely. The DEIR must analyze these and other combined impacts. *Id.*

G. The DEIR Must Analyze the Public Health and Safety Impacts from Fire.

The California Department of Forestry and Fire Protection ("CalFire") has identified the Project site and much of the surrounding area as a Very High Fire Hazard Severity Zone. This is shown in CalFire's 2009 recommended map of very high fire hazard severity zones in the local responsibility area (attached hereto as Exhibit 3) and its 2007 adopted map of very high fire hazard severity zones in the state responsibility area (attached hereto as Exhibit 4).

With such a high local fire risk already, it is imperative that the County closely analyze in the DEIR the additional and cumulative fire risk posed by the Project. This includes the fire ignition threats caused by the use of firearms at the skeet shooting range[7] and the (likely)

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[7] The 2012 Shockey Fire that injured three firefighters and killed one civilian may have been caused by target shooting, though CalFire is still investigating. CalFire, Shockey Fire "Incident Information," webpage (last updated September 27, 2012), http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=754.

associated storage of ammunition, any campfires allowed at the Project's 149 proposed campsites, the likely increased off-highway vehicle use both on the Project site and in nearby areas like the Lark Canyon OHV Park, and the likely increase in smoking from additional visitors and Project users. To help mitigate these impacts, the County should require that the Project applicants and/or operators contribute to funding career staff at the Boulevard Volunteer Fire Station.

The Initial Study concludes that "wildland fires" are a less than significant impact "because the project will comply with the regulations relating to emergency access, water supply, and defensible space specified in the County Fire Code." Initial Study at 27. But the Initial Study *entirely fails* to mention the fire risks from firearm use, ammunition storage, campfires, increased OHV use or increased smoking, let alone demonstrate that compliance with the County Fire Code would adequately mitigate those risks. The DEIR must fully analyze those and the rest of the Project-related fire dangers, as well as the cumulative fire impacts to which the Project would contribute.

H. The DEIR Must Analyze the Project's Noise Impacts.

The Initial Study concludes that the Project would have a less than significant noise impact after mitigation. However, the Initial Study ignores or sweeps under the rug without explanation multiple potentially significant Project noise sources, the racket caused by the Project's *20,000* chickens, the (particularly nighttime) noise from events at the Project's open-air amphitheater (including low-frequency noise), and the noise from rowdy campers. The Initial Study also concludes without supporting evidence or explanation that "the additional project related traffic on nearby roadways are [sic] not anticipated to create any direct and cumulative off-site noise impacts." Initial Study at 37. It is hard to believe that the traffic generated by the up to *2,600* users of the Project would not expose residents on Ribbonwood and McCain Valley Roads – the only two roads providing access to the Project from Interstate 8 – to significant and potentially harmful noise levels.

The DEIR must fully analyze all of these noise impacts, among others, and provide as an appendix the "Noise Analysis prepared by LDN consulting dated July 2013." *Id*. And in analyzing the Project's audible noise impacts, the County should normalize (i.e. add a upward adjustment factor to) its noise emission estimates to account for the fact that the Project area is a rural community with little to no prior exposure to such an expansive recreational project.

I. The DEIR Must Analyze the Project's Direct, Indirect and Embedded Greenhouse Gas Emissions.

The Initial Study states that the "project will complete a [greenhouse gas ('GHG emissions analysis including an inventory of GHG emissions" that "will be presented in the technical report and EIR." Initial Study at 23. The County must ensure that this GHG analysis quantifies the estimated GHG emissions from visitor/user vehicle trips to and from the Project and increased OHV use resulting from the Project, in addition to "GHG emissions . . . generated from [other, e.g. worker] vehicle trips, water consumption, disturbance of soils, consumption of fossil fuels to run various equipment, and construction operations." *Id*.

J. The DEIR Must Analyze the Project's Air Quality Impacts.

As the Initial Study acknowledges, the "project has the potential to significantly contribute to the violation of an air quality standard or significantly contribute to an existing or projected air quality violation, primarily related to traffic, construction activities, and grading operations." Initial Study at 11-13. Thus, as the Initial Study states, the County must prepare "an Air Quality Analysis of project-generated emissions" and analyze the Project's air pollution impacts "in the EIR." *Id*. This is particularly essential since San Diego County "is presently in non-attainment for the 1-hour concentrations under the California Ambient Air Quality Standard (CAAQS) for Ozone (O_3)," as well as the "annual geometric mean and for the 24-hour concentrations of Particulate Matter less than or equal to 10 microns (PM_{10}) under the CAAQS." *Id*. at 12. As part of its air quality analysis, the DEIR must consider the particulate matter and other emissions from any campfires allowed as part of the Project.

The Initial Study also recognizes that the "proposed project would introduce people to odors from the existing on-site chicken coop, horses, and cattle," and confirms that "the air quality analysis and Draft EIR shall evaluate the potential for the Proposed Project to produce objectionable odors." Initial Study at 13. As part of its "objectionable odors" discussion, the DEIR must analyze the impacts to nearby residents of the odors created by any campfires allowed as part of the Project.

K. The DEIR Must Analyze the Project's Many Health and Safety Hazards.

In addition to the health and safety hazards already mentioned – including from polluted water, contaminated soil, fire, noise and air pollution – there are many others the DEIR must analyze. These include the health and environmental hazards caused by the Project's use of PVC and Project-related exposure to disease-carrying vectors and Valley Fever.

1. PVC Use

As shown in the Project's Plot Plan/Preliminary Grading Plan, the Project would use PVC piping to distribute potable water. PVC, however, "poses substantial and unique environmental and human health hazards." Joe Thornton, "Environmental Impacts of Polyvinyl

Chloride (PVC) Building Materials: A Briefing Paper for the Healthy Building Network,"[8] p. 5 (attached hereto as Exhibit 5). Indeed, as Dr. Thornton explains, "[i]n most of Europe, governments have eliminated certain PVC uses for environmental reasons." *Id*. These hazards include the leaching of lead (and other metal stabilizers) and carcinogenic gas vinyl chloride from PVC pipes into drinking water, as well as the production and release of numerous toxic byproducts throughout PVC's lifecycle, from fabrication to disposal and destruction. Exhibit 5; EPA, "Basic Information about Vinyl Chloride in Drinking Water," website (last updated May 21, 2012), http://water.epa.gov/drink/contaminants/basicinformation/vinyl-chloride.cfm. The County must analyze these impacts in the DEIR and consider alternatives to PVC piping, such as ductile iron, copper, HDPE and PEX. These and other alternatives are discussed in the Healthy Building Network's "PVC-Free Pipe Purchasers' Report" (attached hereto as Exhibit 6).

2. Exposure to Disease-Carrying Vectors

As discussed above in sections I(D) and I(E), it is impermissible for the County to omit analysis in the DEIR of a potentially significant impact based on a conclusory assertion that it would be mitigated. The Initial Study nonetheless makes this mistake once again in concluding that, while "the project may expose people to significant risk of injury or death involving [disease-carrying] vectors" like cattle, horses and chickens, such a health hazard would be a "Less than Significant Impact" and need not be analyzed in the DEIR because the risk would be mitigated through "an existing Vector Management Plan." Initial Study at 28; NOP Documentation at 2. This does not satisfy CEQA. CEQA requires that the County discuss in the Project DEIR *both* the "significant risk of injury or death involving vectors" *and* the measures to mitigate that impact. Initial Study at 28 (quote); Pub. Res. Code § 21002.1; Guidelines §§ 15126, 15126.2, 15126.4. And where the mitigation measures themselves create health and environmental hazards, as with poisonous chemicals used to kill rats for example, the DEIR must analyze those impacts too.

3. Exposure to Valley Fever

Valley Fever is a potentially fatal illness with pneumonia-like symptoms that is caused by the fungus *Coccidioides immitis* that lives in the soil in arid areas, including parts of San Diego County. "Workers who dig or otherwise disturb soil containing the *Coccidioides immitis* fungus are at risk of getting the illness." California Department of Public Health, "Preventing Work-Related Valley Fever (Coccidiomycosis)," website (last updated May 5, 2014), http://www.cdph.ca.gov/programs/ohb/Pages/Cocci.aspx. Because *Coccidioides immitis* occurs in some San Diego County soils and has caused Valley Fever there, and because the Project would entail substantial grading and other soil-disturbing activities, Project workers and users are

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[8] Retrieved on May 15, 2014 from http://mts.sustainableproducts.com/SMaRT/ThorntonRevised.pdf.

at risk of contracting Valley Fever. The County must analyze that risk and measures to mitigate it in its DEIR for the Project. In so doing, the County should consult the California Department of Public Health's guide to preventing work-related Valley Fever, which is attached hereto as Exhibit 7.

L. The DEIR Must Analyze the Project's Impacts to Local Roads.

The Project, with a maximum occupancy of *2,600 people*, would cause a significant increase in traffic on the two local roads from which the Project could be accessed, Ribbonwood Road and McCain Valley Road. It is essential for both the health and safety of the residents along those roads and for emergency services access in the case of wildfire or other incidents that both roads be maintained in good and easily driveable conditions. The DEIR must analyze the Project's impacts on local roads, including Ribbonwood Road and McCain Valley Road, and discuss measures to mitigate those impacts.

IV. CONCLUSION

The Rough Acres Ranch Project would – in combination with the Tule Wind Project and other planned regional developments – ruin the quietude, peacefulness and sense of place for the current residents and visitors in the area. It would also threaten the health and welfare of the area's residents, visitors and wildlife. And, without consideration for the ongoing statewide drought, the Project would further tax the already strained regional groundwater supplies. For these reasons and others, Backcountry opposes the Project as proposed and stresses the need for thorough and transparent CEQA compliance. Among other CEQA tasks, the County must include in the DEIR a complete and accurate Project description, and must fully analyze in the reasonable Project alternatives and adverse impacts identified by Backcountry above, as well as identify and evaluate measures to mitigate those impacts.

Respectfully submitted,

Stephan C. Volker
Attorney for Backcountry Against Dumps and
Donna Tisdale

SCV:taf

LIST OF EXHIBITS

1. Federal Environmental Protection Agency, October 2008, Campo-Cottonwood Sole Source Aquifer Map;

2. U.S. Fish & Wildlife Service, August 11, 2003, Recovery Plan for the Quino Checkerspot Butterfly (*Euphydryas editha quino*);

3. CalFire, June 12, 2009, Map of Very High Fire Hazard Severity Zones in the Local Responsibility Area as Recommended by CalFire;

4. CalFire, November 7, 2007, Map of Very High Fire Hazard Severity Zones in the State Responsibility Area;

5. Joe Thornton, "Environmental Impacts of Polyvinyl Chloride (PVC) Building Materials: A Briefing Paper for the Healthy Building Network," available at http://mts.sustainableproducts.com/SMaRT/ThorntonRevised.pdf;

6. Jamie Harvie and Tom Lent, "PVC-Free Pipe Purchasers' Report," prepared for the Healthy Building Network, available at http://www.healthybuilding.net/pvc/pipes_report.pdf;

7. California Department of Public Health, June 2013, "Preventing Work-Related Coccidioidomycosis (Valley Fever)," available at http://www.cdph.ca.gov/programs/hesis/documents/coccifact.pdf.

EXHIBIT 1

Campo-Cottonwood Sole Source Aquifer

Designated Area

Notes and Explanation:

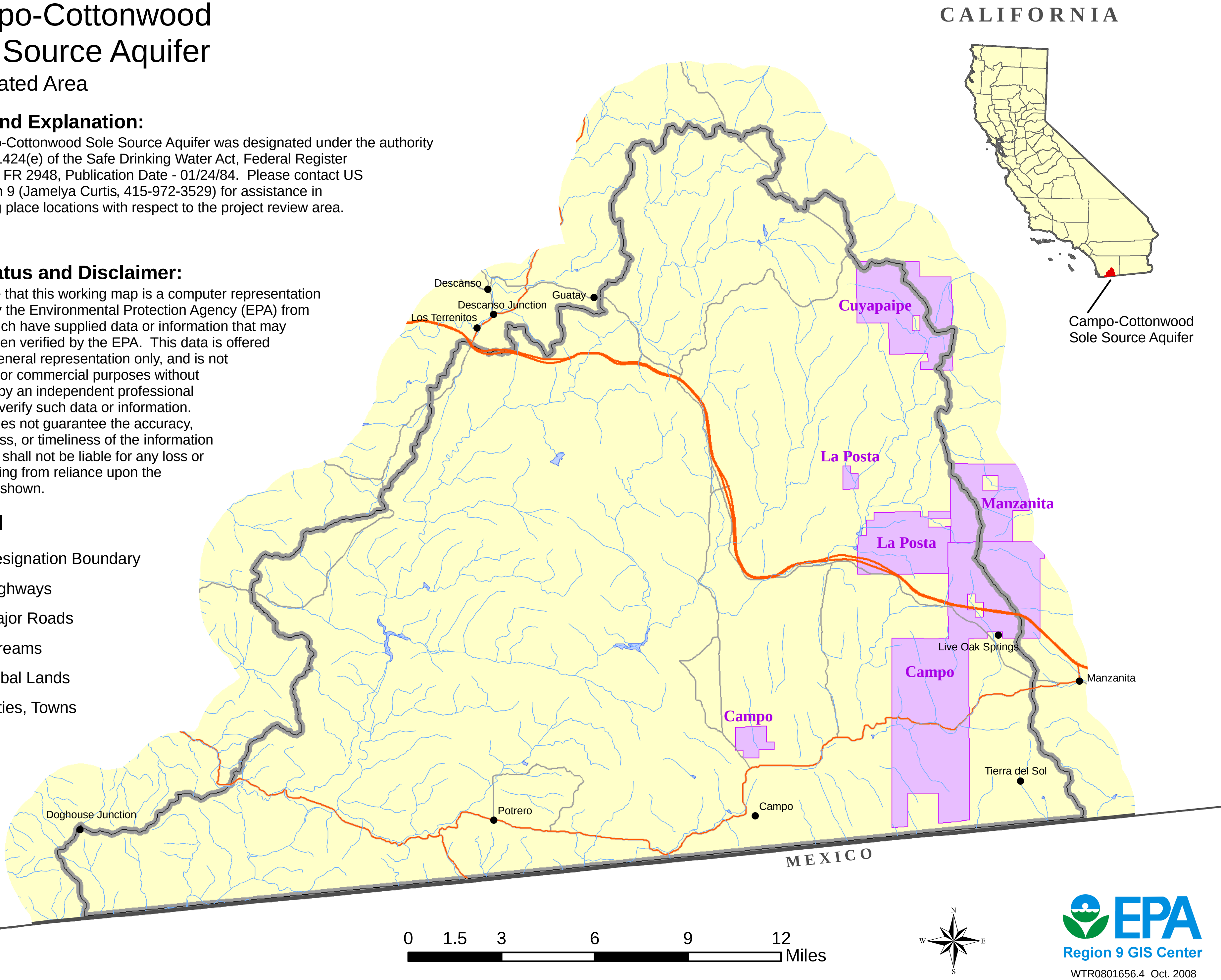
The Campo-Cottonwood Sole Source Aquifer was designated under the authority of Section 1424(e) of the Safe Drinking Water Act, Federal Register Citiation-49 FR 2948, Publication Date - 01/24/84. Please contact US EPA Region 9 (Jamelya Curtis, 415-972-3529) for assistance in determining place locations with respect to the project review area.

Map Status and Disclaimer:

Please note that this working map is a computer representation compiled by the Environmental Protection Agency (EPA) from sources which have supplied data or information that may not have been verified by the EPA. This data is offered here as a general representation only, and is not to be used for commercial purposes without verification by an independent professional qualified to verify such data or information. The EPA does not guarantee the accuracy, completeness, or timeliness of the information shown, and shall not be liable for any loss or injury resulting from reliance upon the information shown.

Legend

- Designation Boundary
- Highways
- Major Roads
- Streams
- Tribal Lands
- Cities, Towns



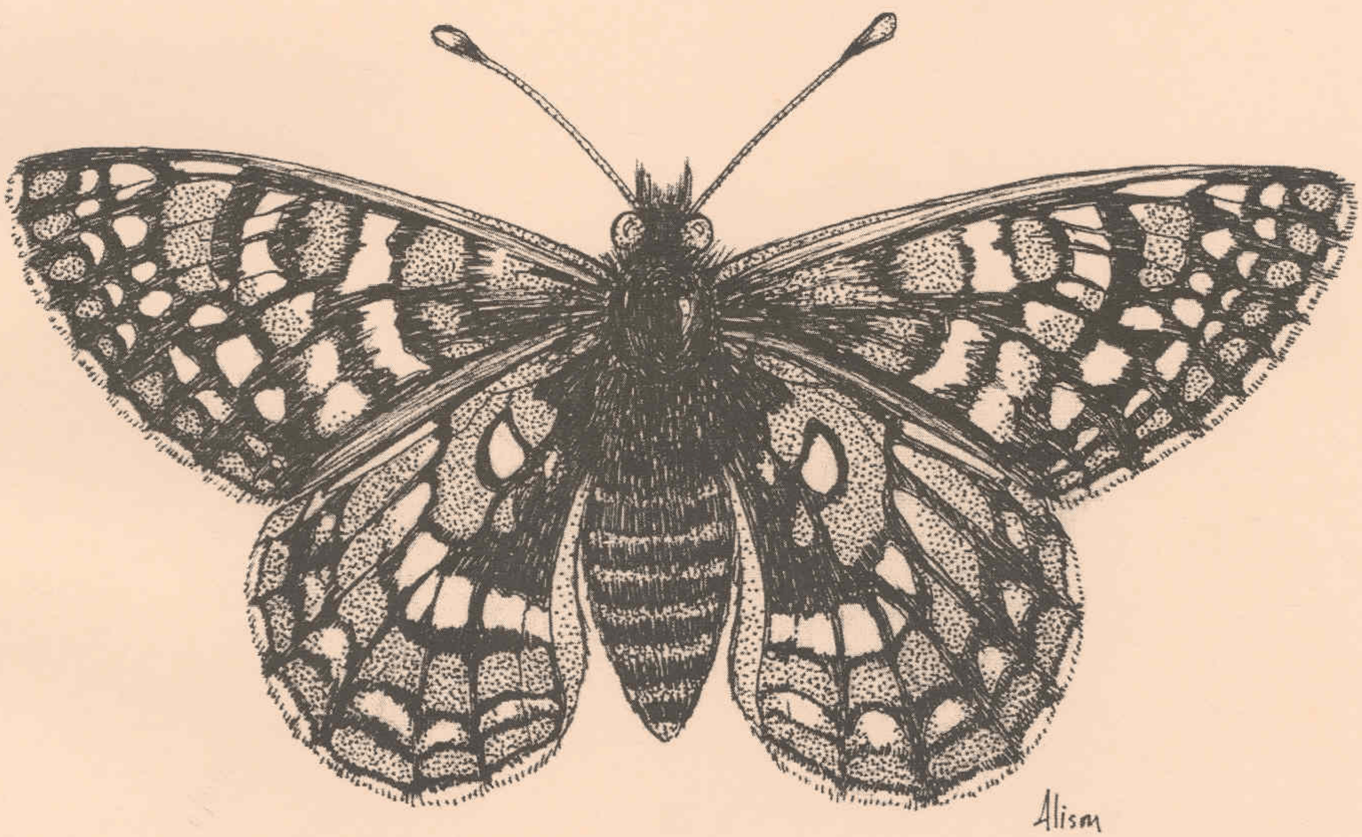
Region 9 GIS Center

WTR0801656.4 Oct. 2008

EXHIBIT 2

U.S. Fish & Wildlife Service

Recovery Plan for the Quino Checkerspot Butterfly
(Euphydryas editha quino)



RECOVERY PLAN

FOR THE

QUINO CHECKERSPOT BUTTERFLY

(*Euphydryas editha quino*)

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved: ______________________________
Manager, California/Nevada Operations Office
Region 1, U.S. Fish and Wildlife Service

Date: AUG 11 2003

DISCLAIMER

Recovery plans delineate actions required to recover and protect federally listed plant and animal species. We (the U.S. Fish and Wildlife Service) publish recovery plans, sometimes preparing them with the assistance of recovery teams, contractors, State agencies, and other affected and interested parties. Recovery teams serve as independent advisors to the Fish and Wildlife Service. Draft recovery plans are published for public review and submitted to scientific peer review before we adopt them. Objectives of the recovery plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific recovery actions and do not necessarily represent the view, official position, or approval of any individuals or agencies involved in the plan formation other than our own. They represent our official position only after they have been signed by the Director, Regional Director, or California/Nevada Operations Manager as approved. Approved recovery plans are subject to modification as directed by new findings, changes in species status, and the completion of recovery actions.

Literature Citation should read as follows:

U.S. Fish and Wildlife Service. 2003. Recovery Plan for the Quino Checkerspot Butterfly (*Euphydryas editha quino*). Portland, Oregon. x + 179 pp.

Additional copies may be purchased from:
Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, MD 20814-2158
(301)492-6403 or 1-800-582-3421
Fax: (301)564-4059
Email: fwrs@mail.fws.gov
http://fa.r9.fws.gov/r9fwrs
The fee for the plan varies depending on the number of pages in the plan.

An electronic version of this recovery plan will also be made available at http://pacific.fws.gov/ecoservices/endangered/recovery/default.htm and at http://endangered.fws.gov/recovery/index.html#plans.

PRIMARY AUTHORS

Quino Checkerspot Butterfly Recovery Team

Edith Allen, PhD, Team Chair
Mark Dodero
Travis Longcore, PhD
Dennis Murphy, PhD
Camille Parmesan, PhD
Gordon Pratt, PhD
Michael Singer, PhD

This recovery plan was prepared by:
Alison Anderson, PhD
Carlsbad Fish and Wildlife Office
U.S. Fish and Wildlife Service

Primary scientific review and contributions were provided by the Quino Checkerspot Butterfly Recovery Team. Independent scientific review and contributions were provided by Ken Osborne.

ACKNOWLEDGMENTS

We greatly appreciate the numerous individuals who, over the course of years, contributed to the conservation of the Quino checkerspot butterfly and the development of this recovery plan, including lepidopterists and researchers who collected the historical data we used. Biologists who deserve credit for significant recent Quino checkerspot butterfly data contributions include: Greg Ballmer, Guy Bruyea, Mark Dodero, John and Thomas Emmel, David Faulkner, Jeremiah George, Dave Hawks, Rudi Mattoni, Dennis Murphy, Ken Osborne, Gordon Pratt, Camille Parmesan, Cissy Pierce, Erica Romero, and Fred Sproul. U.S. Fish and Wildlife Service staff who helped collect data and/or made other contributions to this recovery plan include: Ken Berg, Grant Canterbury, Karin Cleary-Rose, Patricia Cole, Art Davenport, Mark Elvin, Nancy Gilbert, Eric Hein, Nancy Kehoe, Douglas Krofta, John Martin, Brenda McMillan, Christopher Nagano, Bill Ostheimer, Marj Nelson, Michelle Morgan, and Susan Wynn. Stacey Love, Emilie Luciani, Tony McKinney, and Ed Turner assisted and advised on the use of the Geographic Information System (GIS) capabilities and development of Recovery Unit maps.

EXECUTIVE SUMMARY

Current Status: The Quino checkerspot butterfly (*Euphydryas editha quino*), is federally listed as endangered. This taxon occurs in San Diego and Riverside Counties and several localities in Baja California Norte, Mexico. Although no long-term empirical monitoring of populations has been conducted, some conclusions may be drawn regarding the species' overall status. The Quino checkerspot butterfly has apparently undergone a limited increase in abundance and distribution following its disappearance during the prolonged 1980's drought. However, current species abundance and distribution remain far below the pre-drought 1970's levels, and there is no evidence that the long-term decline due to human impacts has slowed (see section I.C.5 below, Metapopulation Resilience). Although large portions of occupied habitat are under public ownership, few, if any, known population distributions (preliminarily delineated in this document as occurrence complexes, further defined below) are entirely protected. There are no populations currently known to be resilient. Destruction and degradation of occupied habitat continues throughout the range of the Quino checkerspot butterfly, and some level of ongoing degradation exists in all occupied habitat.

Habitat Requirements and Limiting Factors: The Quino checkerspot butterfly is found in association with topographically diverse open woody canopy landscapes containing low to moderate levels of nonnative vegetation compared to disturbed habitat. Vegetation types that support the Quino checkerspot butterfly include coastal sage scrub, open chaparral, juniper woodland, and native grassland. Soil and climatic conditions, as well as other ecological and physical factors, affect the suitability of habitat within the species' range. Urban and agricultural development, invasion of nonnative species, habitat fragmentation and degradation, and other human-caused disturbances have resulted in substantial losses of habitat and declines in habitat suitability throughout the species' historic range. Conservation needs include protection and management of landscape connectivity (habitat patches and intervening dispersal areas); habitat restoration and enhancement; and establishment of a formal Quino checkerspot butterfly captive breeding program.

The recovery strategy focuses on landscape-level protection of metapopulations that experience marked fluctuations in density and geographic distribution on a scale of 5 to 10 years. This recovery plan identifies six recovery units (Northwest Riverside, Southwest Riverside, South Riverside, South Riverside/North San Diego, Southwest San Diego, and Southeast San Diego). Recovery units are the major units for managing recovery efforts. Most recovery units contain one or more existing core (relatively large) occurrence complexes. A number of factors were considered in identifying recovery units, primarily biological and genetic factors, political boundaries, and ongoing conservation efforts. In some instances, recovery unit boundaries were modified to maximize efficiency of reserves, encompass areas of common threats, or accommodate logistic concerns. Recovery units may include areas of apparently suitable networks of habitat patches and dispersal areas that are not known to be occupied, when biological evidence warrants. Biologically, Quino checkerspot butterfly recovery units include areas within which gene flow is currently possible.

Recovery Priority: 6C, per criteria published in the Federal Register (U.S. Fish and Wildlife Service 1983a, 1983b). The priority is based on designation as a subspecies with a high degree of threat, a moderate to low potential for recovery, and existing conflict between the species' conservation and development.

Objectives: The overall objective of this recovery plan is to reclassify the Quino checkerspot butterfly from endangered to threatened status and ensure the species' long-term conservation. Interim goals include: (1) protect and manage habitat supporting known current population distributions (occurrence complexes) and landscape connectivity between them; (2) maintain or create resilient populations; and (3) conduct research necessary to refine recovery criteria. Reclassification to threatened status is appropriate when a taxon is no longer in danger of extinction throughout a significant portion of its range. Because data upon which to base reclassification decisions are incomplete, downlisting criteria in this recovery plan are necessarily preliminary. There are insufficient data on which to base delisting criteria at this time.

Recovery Criteria:

The Quino checkerspot butterfly could be downlisted to threatened when the following criteria are met:

1) Permanently protect the habitat within occurrence complexes (estimated occupied areas based on habitat within 1 kilometer (0.6 mile) of recent butterfly occurrences; see section I.D below, Distribution and Habitat Considerations), in a configuration designed to support resilient populations. One or more occurrence complexes may belong to a single greater population distribution, or an occurrence complex may contain more than one whole or partial population distributions. When population distributions are determined, they will replace the occurrence complex as the protected unit. There are currently 46 described occurrence complexes.

2) Conduct research including: determine the current short-term and potential long-term distributions of populations and associated habitat; conduct preliminary modeling of metapopulation dynamics for core occurrence complexes identified in section I.D below (Distribution and Habitat Considerations).

3) Permanently provide for and implement management of occurrence complexes (or population distributions when delineated) to restore or enhance habitat quality and population resilience. Management should be implemented as described in Recovery Action 1 (section II.C below, Recovery Action Narrative).

4) The protected, managed (conserved) population segments within core occurrence complexes (or population distributions when delineated) must demonstrate evidence of resilience. Evidence of resilience is demonstrated if a decrease in the number of occupied habitat patches over a 10- to 20-year period within an occurrence complex (or population distribution when delineated) is followed by increases of equal or greater magnitude. Monitoring must be initiated in the third of three years of favorable climate (total annual January and February precipitation within one standard error of the average total for those months over the past 30 years, based on local or proxy climate data).

Populations that do not demonstrate resilience after 20 years should be augmented and monitoring reinitiated.

5) One additional population should be documented or introduced within the Lake Matthews population site (formerly occupied, not known to be currently occupied) in the Northwest Riverside Recovery Unit. At least one of the extant populations outside of current recovery units (*e.g.* the San Vicente Reservoir occurrence complex) must meet resilience specifications above unless an additional population is established or documented within 10 kilometers (6 miles) of the ocean (a more stable marine climate influence should minimize susceptibility to drought and reduce probability of extirpation).

6) Establish and maintain a captive propagation program for purposes of maintenance of representative refugia populations, research, and reintroduction and augmentation of wild populations as appropriate.

7) Initiate and implement a cooperative outreach program targeting areas where Quino checkerspot butterfly populations are concentrated in western Riverside and southern San Diego Counties.

At present there is insufficient information about the biology of the species to establish criteria and timeframes for delisting. Research needs for development of delisting criteria are described under Recovery Action 6 below.

<u>Actions Needed</u>:

1) Protect and manage as much remaining habitat as possible that is part of the known population distributions in a configuration designed to support resilient metapopulations in all recovery units. Conduct intensive restoration of agricultural and grazed areas and degraded habitat in the Southwest San Diego and Southwest Riverside Recovery Unit core occurrence complexes.
2) Continue yearly reviews and monitoring as needed as part of adaptive management until resilient occurrence complexes or populations are achieved.
3) Assess and augment lowest density populations.
4) Establish and maintain a captive propagation program.
5) Develop and implement community outreach projects.
6) Conduct research needed to refine recovery criteria and guide conservation

efforts (survey areas between and around occurrence complexes to determine where there is intervening and/or additional landscape connectivity; map habitat patch distributions; monitor habitat loss; conduct preliminary modeling of metapopulation dynamics; investigate key natural history questions and threats).
7) Locate or reintroduce at least one population within the Lake Matthews population site.
8) Reduce firearm use and unauthorized trash dumping in habitat areas.
9) Continue dialogue with the Cahuilla Band of Indians.
10) Survey for habitat and/or undocumented populations within recovery units.
11) Survey other areas that could possibly support Quino checkerspot butterfly populations.
12) Enter into dialogue with Baja California, Mexico, nongovernmental organizations and local governments.

Total Estimated Cost to Meet Interim Recovery Objectives: $ 140,990,000 + additional costs that cannot be determined at this time.

Date of Recovery: Downlisting could be initiated in 2018 or sooner, if recovery criteria are met.

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I. INTRODUCTION

A. Brief Overview

The distribution and abundance of the Quino checkerspot butterfly (*Euphydryas editha quino*) have been dramatically reduced during the past century as a result of agricultural and urban development and other land-use changes in southern California. Immediate protection and management of the habitats that support the species, initiation of a captive propagation program, and development of the monitoring scheme and research agenda described in this recovery plan will be necessary to prevent extinction of the Quino checkerspot butterfly.

The Quino checkerspot butterfly (Figure 1) is currently known only from western Riverside County, southern San Diego County, and northern Baja California, Mexico, although the historic range of this taxon included much of coastal California south of Ventura County and inland valleys south of the Tehachapi Mountains (Figure 2). More than 75 percent of the Quino checkerspot butterfly's historic range has been lost (Brown 1991, Figure 2), including more than 90 percent of its coastal mesa and bluff distribution. Quino checkerspot butterfly populations appear to have been reduced in number and size by more than 95 percent range-wide, primarily due to direct and indirect human impacts including habitat loss and fragmentation, invasion of nonnative plant species, and disrupted fire regimes (D. Bauer, D. Murphy, and M. Singer, pers. comm.). In this recovery plan, populations associated with Quino checkerspot butterfly occurrences recorded in the 1990's or more recently are considered to be extant; any older records are deemed historic occurrences.

This recovery plan describes six geographic areas called recovery units (Figure 3), which are based primarily on habitat regions that support extant Quino checkerspot butterfly populations. Habitat regions are described below in section I.D (Distribution and Habitat Considerations), and the recovery units associated with these habitat regions are specifically delineated in section I.G.1. (Recovery Units). Recovery units contain both lands that are considered essential and lands that are not considered essential to the conservation of the species. Determination of management needs and habitat configurations required for long-term persistence of the species will require further surveys,

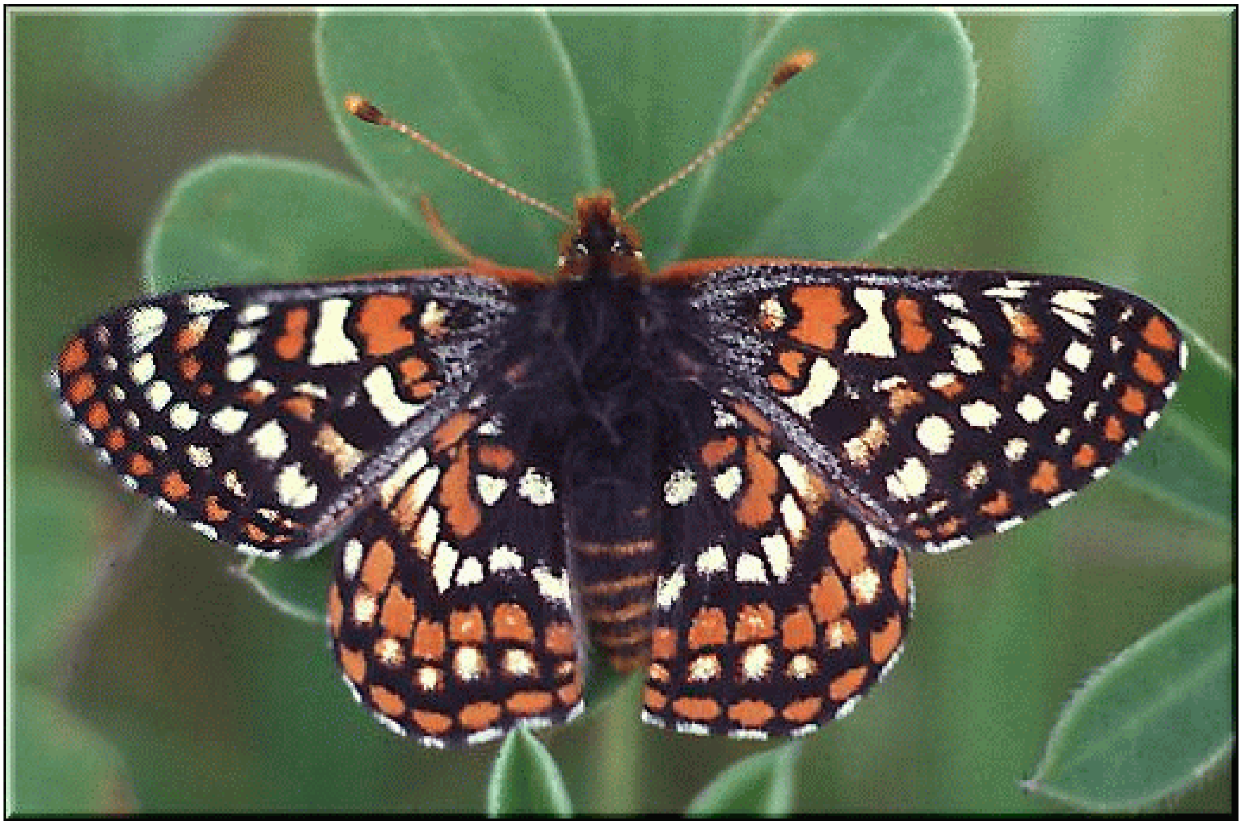


Figure 1. Quino checkerspot butterfly. Photo used by permission of Guy Bruyea.

UNITED STATES
Department of the Interior
U.S. Fish and Wildlife Service
Carlsbad, California

DATA SOURCES:

BASE DATA - Teale Data Center, Sandag, USFWS

QUINO DATA - Year 2002 Quino Recovery Areas USFWS based on biological staff input, data compiled from the above Base Data Sources.

Map prepared by Edwin Turner
July 1, 2003

Quino Checkerspot Butterfly Historic U.S. Distribution

30 0 30 60 Miles

30 0 30 60 90 Kilometers

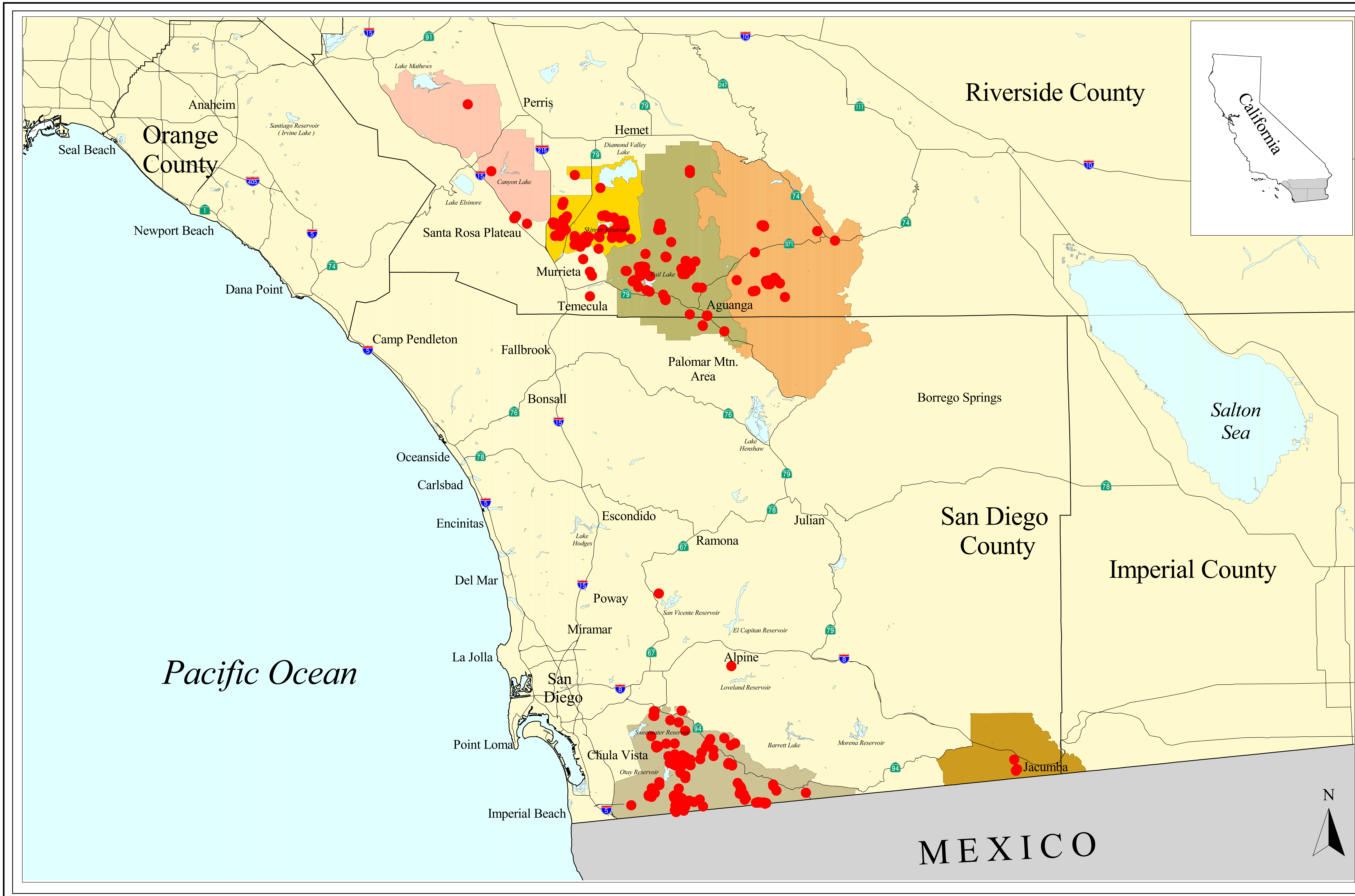
70000 0 70000 140000 210000 Feet

Occurrence symbols cover a geographic area of 2 kilometers (diameter)

Quino Data Locations

- 1890 - 1986
- 1986 - 2003

Figure 2



Quino Checkerspot Butterfly Recovery Units and Recent U.S. Occurrences

UNITED STATES
Department of the Interior
U.S. Fish and Wildlife Service
Carlsbad, California

20 0 20 40 Miles
20 0 20 40 60 Kilometers
50000 0 50000 100000 150000 Feet

Quino Data and Recovery Units

- Northwest Riverside
- Southwest Riverside
- South Riverside
- South Riverside / North San Diego
- Southwest San Diego
- Southeast San Diego
- 1986 - 2003

BASE DATA - Teale Data Center, USFWS

QUINO DATA - Year 2002 Quino Recovery Areas USFWS
based on biological staff input, data compiled from the above Base Data Sources.

/stem/edstemp/quino/aprs/qfru_0703.apr
July 17, 2003

Some occurrences are within areas recently authorized for development.
Occurrence symbols cover a geographic area of 2 kilometers (diameter).

Figure 3

monitoring, modeling, and other research described below in section II.C (Recovery Action Narrative). Habitat within the current known distribution of the species ranges from moderately to highly disturbed and invaded by nonnative species. No pristine habitat remains for the butterfly north of the international border (D. Murphy, G. Pratt, M. Dodero, and C. Parmesan, pers. comm.).

We (the U.S. Fish and Wildlife Service) listed the Quino checkerspot butterfly as an endangered species on January 16, 1997 (U.S. Fish and Wildlife Service 1997a). On February 7, 2001, we proposed critical habitat for the Quino checkerspot butterfly (U.S. Fish and Wildlife Service 2001a), and on April 15, 2002, final critical habitat was designated (U.S. Fish and Wildlife Service 2002a). This species has a Recovery Priority of 6C, based on the classification system published in the Federal Register (U.S. Fish and Wildlife Service 1983a, 1983b). This priority number reflects the subspecific status of the butterfly, a high degree of threat, a moderate to low potential for recovery, and existing conflicts with construction or other land development. This recovery plan attempts to reduce the risk of the species' extinction by recommending protection and long-term management of habitat necessary to support resilient populations. Due to highly degraded habitat conditions and very low population sizes range-wide, long-term adaptive management will also be required. Protection of high-quality habitats with resilient Quino checkerspot butterfly populations in Baja California, Mexico, is also needed.

B. Description and Taxonomy

The Quino checkerspot butterfly is a member of the family Nymphalidae (brush-footed butterflies) and the subfamily Melitaeinae (checkerspots and fritillaries). The Quino checkerspot butterfly is a subspecies of the Edith's checkerspot butterfly (*Euphydryas editha*); it differs from other subspecies in a variety of characteristics including size, wing coloration, and larval and pupal phenotype (Mattoni *et al.* 1997).

The taxon now commonly called the Quino checkerspot butterfly has undergone several nomenclatural changes. It was originally described as *Melitaea quino* (Behr 1863). Gunder (1929) reduced it to a subspecies of *Euphydryas chalcedona*. At the same time, he described *Euphydryas editha wrighti* from a checkerspot butterfly specimen collected in San Diego. After reexamining

Behr's descriptions and specimens, Emmel *et al.* (1998) concluded that the Quino checkerspot butterfly should be associated with *E. editha*, not *E. chalcedona*, and that it was synonymous with *E. editha wrighti*. Because *E. editha wrighti* is a junior synonym for the Quino checkerspot butterfly, *E. editha quino* is now the accepted scientific name.

The adult Quino checkerspot butterfly (Figure 1), has a wingspan of approximately 4 centimeters (1.5 inches). The dorsal (top) sides of the wings have a red, black, and cream colored checkered pattern; the ventral (bottom) sides are dominated by a checkered red and cream pattern. The abdomen of the Quino checkerspot butterfly has red stripes across the top. After their second molt, Quino checkerspot butterfly larvae can be recognized by the characteristic dark-black coloration and row of 8 to 9 orange tubercles (fleshy/hairy extensions) on their back. Before their first molt, larvae have a predominantly yellow coloration, and before their second molt they are grey with black markings (G. Pratt, pers. comm. 1999). Pupae are mottled black on a pale blue-gray background, and extremely cryptic. Inexperienced surveyors in the field may confuse the Quino checkerspot butterfly with three other co-occurring butterfly species: the chalcedon or variable checkerspot (*Euphydryas chalcedona*), Gabb's checkerspot (*Chlosyne gabbi*), and Wright's checkerspot (*Thessalia leonira wrighti*). Chalcedon checkerspot butterfly adults are darker and often larger than Quino checkerspot butterflies, and have white abdominal stripes and spots instead of red stripes. Male and female Gabb's checkerspot butterfly adults have a more orange appearance than Quino checkerspot butterflies, but female coloration is of higher contrast and may closely resemble Quino checkerspot butterflies. Gabb's checkerspot butterflies can be differentiated from Quino checkerspot butterflies by silver-white spots on their underwings, the lack of red abdominal stripes, and a scalloped forewing margin. Because adult morphology of *Euphydryas* butterfly species is variable, a combination of morphological characters should be used to distinguish them from similar species in the field.

C. Life History

Few specific studies of Quino checkerspot butterfly biology have been conducted. One paper reported observations of Quino checkerspot butterfly population dynamics (Murphy and White 1984) and another addresses local movement behavior (White and Levin 1981). More recently, one quantitative larval habitat use study (Osborne and Redak 2000) and two distribution studies (Parmesan 1996 and Pratt *et al*. 2001) have been published. Therefore, most information in this section is drawn from the abundant literature reporting research on other subspecies of *Euphydryas editha*, in particular the bay checkerspot butterfly (*E. editha bayensis*). Although it is generally true that different subspecies of *E. editha* have similar life histories, such assumptions must be made with caution, especially with regard to characteristics affected by unique local environmental conditions.

1. Life Cycle

The life cycle of the Quino checkerspot butterfly (Appendix I) typically includes one generation of adults per year, with a 4 to 6 week flight period beginning from late January to early March and continuing as late as early May, depending on weather conditions (Emmel and Emmel 1973, U.S. Fish and Wildlife Service 2003). If sufficient rain falls in late summer or early fall, a rare second generation of reduced numbers may occur (Mattoni *et al.* 1997). Females are usually mated on the day they emerge from pupae, and lay one or two egg clusters per day for most of their adult life. Adults live from 10 to 14 days; however, adult emergence from pupae is staggered, resulting in a 1 to 2 month flight season. Peak emergence in most brush-footed (nymphalid) butterfly species, and probably for the Quino checkerspot butterfly as well, occurs shortly after the beginning of the flight season, usually in the second week (Zonneveld 1991). Eggs deposited by adults hatch in 10 to 14 days.

The periods between molts (shedding skin) are called instars. Larvae that hatch from eggs are in the first instar, and may subsequently undergo as many as 7 instars prior to pupation. During the first two instars, prediapause larvae cannot move more than a few centimeters and are usually restricted to the plant on which eggs were laid (the primary host plant species). Prediapause larvae spin a web and feed in groups. Webs are fairly conspicuous and associated with visible feeding damage to the plant. During the third instar (about 10 days after hatching), larvae are able to move to new individual host plants. Third instar larvae usually wander independently in search of food, and may switch from feeding on the plant on which they hatched to another plant of the same species (primary host plant), or another host plant species (secondary host plant).

During larval development, the host plants age, eventually drying out and becoming inedible (senescence). At the time of host plant senescence, if larvae are old enough and have accumulated sufficient reserves, they are able to enter diapause. Larvae have been observed entering diapause in the lab as early as the second instar, and surviving to the next season (K. Osborne and G. Pratt, pers. comm.).

Diapause is a resting state that enables larvae to maintain a low metabolic rate and may occur during periods when host plants are not available. While in diapause, larvae are much less sensitive to climatic extremes and can tolerate temperatures from over 49 degrees Celsius (120 degrees Fahrenheit) to below freezing (M. Singer, pers. comm.). The larval exterior, or skin, is distinctive during diapause, becoming much blacker with denser "hairs" (setae) than earlier instars (Appendix I). Diapausing *Euphydryas editha* larvae have been observed curled up under rocks or sticks, and enclosed in a light webbing (C. Parmesan and M. Singer, pers. comm.). Although the location of diapausing sites of Quino checkerspot butterfly larvae in the field has not been researched, the presence of clusters of post diapause larvae found near dense grass and shrub cover indicates they may diapause in these areas (Osborne and Redak 2000).

Like many other related butterflies, *Euphydryas editha* larvae can live for several years. One mechanism that generates longevity is repeated diapause (Singer and Ehrlich 1979), which occurs when larvae emerge from diapause, feed, and then re-enter diapause, postponing development until the next year. It has been suggested that Quino checkerspot butterfly larvae may also be able to survive without "breaking" diapause to feed in extremely dry years (G. Pratt, pers. comm.).

It is not known if Quino checkerspot butterfly larvae can store enough energy reserves to prolong diapause without feeding at all for more than a year. However, the Quino checkerspot butterfly's ability to undergo repeated diapause is thoroughly documented. Laboratory studies have repeatedly shown that post-diapause *Euphydryas editha* larvae feeding in early spring are able to re-enter diapause and postpone development another season if food resources are exhausted (G. Pratt and M. Singer, pers. comm.). However, repeated diapause in the field has not been studied, and experts do not agree on how prevalent it might be under typical environmental conditions. There have been rare field observations of larvae that had re-entered diapause (D. Murphy and M. Singer, pers. comm.). For example, M. Singer (pers. comm.) found more than 50 bay checkerspot butterfly larvae that had re-entered diapause in the middle of a patch of host plants that had been totally consumed. Return to diapause may also occur under conditions when plants are unusually dry or developmentally advanced, because poor host plant conditions can result in high larval mortality.

The Recovery Team did agree that under exceptionally poor conditions, most or even all larvae at a site may re-enter diapause, although this occurrence has not been documented in the field. Larvae appear to have a narrow window of time during which diapause may be re-entered. Last instar larvae do not appear to be able to re-enter diapause, and repeated diapause has only rarely been observed in next-to last instar larvae (G. Pratt, pers. comm.). Also, there is probably a significant mortality risk during diapause (Moore 1989), so the likelihood of successful development and reproduction must be lower than the probability of surviving a second season of diapause for repeated diapause to have a fitness benefit. Because Quino checkerspot butterfly larvae can re-enter diapause, it is possible that an adult flight period may only include a portion of the original larval population or may not occur at all in some occupied sites under adverse conditions. From the perspective of judging whether a population has been extirpated, it is important to know that a normally robust population may generate no adults at all in a given year if poor environmental conditions preclude an adult flight period.

Sufficient rainfall, usually during November or December, apparently causes larvae to break diapause. Records of rare late second flight seasons following unusual summer rains indicate that the Quino checkerspot butterfly does not require winter chilling to break diapause, and may not diapause at all under some circumstances (Mattoni *et al.* 1997). Rain stimulates germination and growth of the host plants fed upon by postdiapause larvae. Postdiapause bay checkerspot butterfly larval dispersal has been documented; larvae have been observed to travel up to 3.5 meters (11.5 feet) during a 4-day period (Weiss *et al.* 1987). Greater larval dispersal distances were rare, but movement up to 10 meters (33 feet) per day has been recorded (Weiss *et al.* 1988). During one study of Quino checkerspot butterfly larvae at Lake Skinner, Riverside County, post-diapause larvae were observed to typically move 0.5 to 1 meter (20 to 40 inches) per hour while grazing, many moving up to 30 to 40 meters (100 to 130 feet) during the course of development (K Osborne, pers. comm.) Postdiapause larvae seek microclimates with high solar exposure, which helps speed development (White 1975, Weiss *et al.* 1987, Osborne and Redak 2000).

Because of variable weather during winter and early spring, the time between diapause termination and pupation can range from 2 weeks, if conditions are warm and sunny, to 2 or 3 months, if cold, rainy conditions prevail (G. Pratt, pers. comm.). Postdiapause larvae undergo three to as many as six molts prior to pupating in silken shelters near ground level. Adults emerge from pupae after approximately 10 days, depending on weather (Mattoni *et al.* 1997).

2. Adult Behavior and Resource Use

Adult Quino checkerspot butterflies spend time searching for mates, basking in the sun to thermoregulate, feeding on nectar, defending territories, and (in the case of females) searching for oviposition sites and depositing eggs. The Quino checkerspot butterfly is ectothermic, using air temperatures and sunshine to increase body temperatures to levels required for flight. If air temperature is cool, clear skies and bright sunshine may provide enough thermal power for flight, but flight is not possible below about 16 degrees Celsius (60 degrees Fahrenheit). In warmer air temperatures, flight may still be possible with scattered clouds or light overcast conditions, but has not been observed in very cloudy, overcast, or foggy weather. Adults remain hidden (often roosting in bushes or trees) during fog, drizzle, or rain, and usually avoid flying in windy conditions (sustained winds greater than 24 kilometers [15 miles] per hour). *Euphydryas editha* butterflies generally fly close to the ground in a relatively slow, meandering flight pattern (M. Singer, pers. comm.).

Adult (K. Osborne, pers. comm. 2002) and larval (Osborne and Redak 2000) Quino checkerspot butterflies, like some other subspecies of *Euphydryas editha*, show a tendency to occur in barren spots amidst low-growing vegetation. Quino checkerspot butterflies tend to avoid flying over trees, buildings, or other objects taller than about 2 meters (7 feet), but natural vegetation does not constitute an impermeable barrier to dispersal (D. Murphy, G. Pratt, C. Parmesan, and K. Osborne, pers. comm.). Other subspecies of *E. editha*, whose host plants are more diffusely distributed than the bay checkerspot butterfly, have been observed to fly over tall vegetation (Gilbert and Singer 1973). It is thought that the typically sedentary nature of bay checkerspot butterflies is associated with the well-defined boundaries of their serpentine grassland habitat patches, termed "intrinsic barriers," rather than restriction by true vegetation "barriers" (Gilbert and Singer 1973). Quino checkerspot butterfly thermodynamic requirements and natural avoidance of shaded areas deter flight in densely wooded areas and other types of closed-canopy vegetation (M. Singer, pers. comm.).

Male Quino checkerspot butterflies, and to a lesser extent females, are frequently observed on hilltops and ridgelines (Carlsbad Fish and Wildlife Office GIS Quino checkerspot butterfly database and metafile, Osborne 2001). A number of behaviors characteristic of species commonly found on hilltops have been documented. For example, male Quino checkerspot butterflies have been observed perching consistently in prominent locations on hilltops devoid of host plants and have been seen "attacking" other male Quino checkerspot butterflies as well as other species of butterfly that approach (Osborne 2001, Pratt 2001). Further evidence that *Euphydryas editha* may display hilltopping behavior was found in Colorado, where the males of an *E. editha* population were observed aggregating on hilltops during a time when population densities were low and the females of the species traveled to seek mates (Ehrlich and Wheye 1986, as discussed in Ehrlich and Murphy 1987). Hilltops may also represent centers of Quino checkerspot butterfly population density in some areas. Hilltops appear to be a resource contributing to Quino checkerspot butterfly survival. Because adult Quino checkerspot butterflies are frequently observed on hilltops (U.S. Fish and Wildlife Service database), even in the absence of nearby larval host plants (Osborne 2001), hilltops and ridgelines may be crucial for population survival and therefore should be searched during presence/absence surveys and included in reserve designs.

Bay checkerspot butterflies appear to exhibit sedentary behavior during the majority of their adult life in most seasons. Most bay checkerspot recaptures have occurred within 100 to 200 meters (330 to 660 feet) of release (Ehrlich 1961, 1965, Gilbert and Singer 1973, White and Levin 1981, Harrison 1989, Boughton 1999, 2000). Harrison *et al.* (1988) documented no between-habitat patch transfers of marked bay checkerspot individuals greater than 1 kilometer (0.6 miles). In a second study, only 5 percent of marked adult bay checkerspots were recaptured in a target habitat patch greater than 1 kilometer (0.6 miles) from the point of release (Harrison 1989). Average recapture distances for

Finnish checkerspot butterfly species closely related to the Quino checkerspot butterfly ranged from 151 to 646 meters (495 to 2,119 feet; Wahlberg *et al.* 2002). However, dispersal tendency appears to be relatively plastic in *Euphydryas editha* (White and Levin 1981) and may have evolved to fit local or regional situations (Gilbert and Singer 1973). White and Levin (1981) noted that "It seems likely from the lower return rate in 1972 [a dry year] and from the observed pattern of out-dispersal, that many marked [male Quino checkerspot butterfly] individuals dispersed beyond the area covered by our efforts that year." White and Levin (1981) also noted that when released in Quino checkerspot butterfly habitat in San Diego County, bay checkerspot butterflies behaved more like Quino checkerspot butterflies (moved significantly greater distances) than did bay checkerspot butterflies in their native San Francisco Bay area habitat. Female checkerspot butterflies have been found to be more likely to emigrate than males (Wahlberg *et al.* 2002), and older adults appear to have a greater tendency to disperse as host plant suitability and female egg loads decline (White and Levin 1981, Harrison 1989).

When quality host plants are in short supply, adult Quino checkerspot butterflies apparently respond by dispersing (White and Levin 1981, Murphy and White 1984). Quino checkerspot butterfly dispersal tendency greatly increased in 1977 when population density was extremely high and many habitat patches were defoliated (Murphy and White 1984). Dispersal tendency also increased when densities were low and dry conditions reduced the number and suitability of host plants for depositing eggs (oviposition) (White and Levin 1981). Long-distance dispersal in bay checkerspot butterflies has been documented as far as 6.4 kilometers (4 miles; 1 male) (Murphy and Ehrlich 1980; D. Murphy, pers. comm. 2001), 5.6 kilometers (3.5 miles; 1 male), and 3 kilometers (2 miles; 1 female) (Harrison 1989). Individual long-distance dispersal may be prevalent under certain conditions, but the likelihood of long-distance colonization by a given individual is usually low because environmental conditions promoting dispersal are not likely to also allow successful colonization. In 2002, an unusually dry season throughout the range of the Quino checkerspot butterfly, females did not appear to be dispersing from their natal habitat patches early in the season, despite the lack of suitable host plants on which to oviposit (A. Anderson, pers. observ. 2002, K. Osborne, G. Pratt, pers. comm. 2002).

Dispersal direction in the bay checkerspot butterfly was generally found to be random (Harrison 1989), but dispersing butterflies were likely to move into habitat patches when they passed within 50 meters (160 feet), and were most likely to stay where existing density was lowest (Harrison 1989). Bay checkerspot butterfly research data also suggested that patches separated from a source population by hilly terrain were less likely to be colonized than patches separated by flat ground (Harrison 1989). Harrison (1989) concluded that because establishment rates were low (during her study) and initial dispersal direction was random, relatively large numbers of butterflies must have emigrated from the source population at some point to explain the apparent long-term habitat patch recolonization pattern. High emigration and habitat patch colonization rates probably only occur during rare outbreak years, when high local densities combine with favorable establishment conditions in "unoccupied" patches (not supporting larval development; Harrison 1989). Rare outbreak events are thought to play a crucial role in Quino checkerspot butterfly metapopulation resilience (Murphy and White 1984).

Establishment of local populations in distant habitat patches may be achieved within a single season through dispersal of individual butterflies, or over several seasons through "stepping-stone" habitat patch establishment events. Research conducted during the late 1970's and late 1980's on the Morgan Hill metapopulation of bay checkerspot butterflies recorded island habitat patch reestablishment distances from the mainland habitat patch averaging 3.4 kilometers (2.8 miles), with a minimum individual butterfly movement distance of 1.4 kilometers (0.9 mile) up to a maximum of 4.4 kilometers (2.8 miles) in individual dispersal or stepping-stone movements (Harrison *et al.* 1988). Dispersal studies in sum suggest that long distance movements by individuals are not common, but may be sufficient to allow for infrequent between-patch exchanges of up to 6 kilometers (3.7 miles). Bay checkerspot butterfly habitat patch reestablishment patterns and models suggest that habitat patches as distant as 7 kilometers (4.3 miles) may provide sources of reestablishment for each other via stepping-stone dispersal over a 40- to 50-year period (Harrison 1988).

The selection of specific plant species by *Euphydryas editha* on which to deposit eggs is genetically determined, and strong natural selection can lead to rapid changes in diet (Singer *et al.* 1991). Host plant preference in females can be quantified by measuring the amount of time a butterfly searches before it will deposit eggs on less preferred host plants (Singer *et al.* 1992). The ability of *E. editha* larvae to grow and survive on particular host plant species is variable among individual larvae (Singer *et al.* 1988) and among larval populations (Singer *et al.* 1994, Rausher 1982). When female *E. editha* butterflies fail to encounter preferred host plants, the likelihood of emigration to other suitable habitat patches increases (Thomas and Singer 1987). Host plant preference, host plant availability, and host plant resistance to herbivores all affect butterfly diet, which in turn affects habitat colonization rates and local population persistence (Hanski and Singer 2001). Because aspects of metapopulation dynamics are apparently emergent properties affected by a number of host plant and butterfly characteristics, further research should be conducted on these interactions.

Most Quino checkerspot butterfly ovipositing has been documented on *Plantago erecta* (dwarf plantain). Rahn (1979) described the habitat of *P. erecta* as "dry sandy soil in dunes, grassy hills and flats, and clearings in woods." *Plantago erecta* occurs in southern California within annual forbland, scrub, grassland, and open chaparral plant communities. It can be found on soils with or without cryptogamic crusts (a thin organic crust composed of cyanobacteria, lichens, mosses, and fungi), and is often associated with fine-textured clay soils (Pratt 2001, K. Osborne, pers. comm. 2002). It is not known whether the plant species has an affinity for clay soils in southern California, or the soils reduce competition from invasive nonnative annual forbs and grasses. *Plantago erecta* does not appear to have any special requirements for germination associated with fire. For instance, its seed coat imbibes moisture and forms mucilage (A. Sanders, pers. comm.), which is not a trait of obligate fire-following species. It may become more abundant immediately after a fire because of the reduction of canopy cover and other changes that favor the species. Seed bank persistence and dynamics in *P. erecta* are not well understood, but they may have major impacts on Quino checkerspot butterfly populations, and warrant further research. An apparent high degree of annual turnover of *P. ovata* (desert indianwheat plantain) seed was observed at Jasper Ridge (N. Chiariello, pers. comm.). However, at Lower Otay Lakes, San Diego County, bouts of total defoliation of host plant patches prior to seed set were followed by dense germination the following year, indicating that the seed bank persists at least 2 years in that area (Murphy and White 1984). Female Quino checkerspot butterflies appear to prefer ovipositing on individual *P. erecta* plants that exhibit a more spreading growth - specifically, on leaves closest to the ground (Pratt 2001). *Plantago erecta* flowers in April and May (Rahn 1979).

Another apparently important, but only recently documented, primary host plant is *Antirrhinum coulterianum* (white snapdragon; Pratt 2001). All Quino checkerspot butterfly egg and larval clusters found during the 2001 season in the Silverado Occurrence Complex, Riverside County (see section I.D, Distribution and Habitat Considerations), were on this plant species. *Antirrhinum coulterianum* appears to be a facultative fire-follower in nondesert areas; Thompson (1988) described the plant's habitat as follows:

> This species can be found dependently, year after year, in desert plant communities, often growing between shrubs. In parts of its range that are dominated by chaparral or coastal sage plant communities, fire or other disturbance seems to be required for the appearance of this species; it is on burns in these plant communities that the plants reach their largest size; a few comparatively small plants can be found in these areas at other times, usually on exposed or disturbed sites.

Antirrhinum coulterianum is generally found between 2 and 520+ meters (5 and 1,700+ feet) in elevation and flowers from April through July (Thompson 1988); thus its availability for larval consumption early in the season may be similar to the availability of *Plantago* host species, although it probably remains edible longer because of its larger, more robust morphology.

Antirrhinum coulterianum displays a number of morphological characteristics that make it unique in the genus *Antirrhinum* (Thompson 1988), and one of them may explain why it is the only species of this genus reported to be a primary host plant of *Euphydryas editha*. Large individuals often produce a substantial cluster of spreading leaves close to the ground (Thompson 1988), similar to the growth form of *Plantago erecta* apparently preferred by female Quino checkerspot butterflies for oviposition.

The hypothesis that *Antirrhinum coulterianum* played an important role in the evolution and ecology of the Quino checkerspot butterfly is also corroborated by the plant species' distribution relative to that of the butterfly. *Antirrhinum coulterianum* has the most restricted range of any of the Quino checkerspot butterfly's primary host plant species. The plant species' range also corresponds very closely with the historic range of the Quino checkerspot butterfly (Figure 2), and the Southwest California Floristic Province (Hickman 1996). If fire-following populations of *A. coulterianum* were an essential component of Quino checkerspot butterfly habitat prior to the advent of fire suppression practices, that would partly explain the absence of recent Quino checkerspot butterfly observations in parts of its historic range, such as central San Diego County and the Santa Ana Mountains in Orange County. Further research into the current and historic relationships between the Quino checkerspot butterfly and *A. coulterianum* should be conducted.

Another species of *Plantago* that was recently documented as a primary host plant for the Quino checkerspot butterfly is *Plantago patagonica* (woolly plantain; Pratt 2000, 2001). *Plantago patagonica* is the only species of *Plantago* found in the Silverado Occurrence Complex (see section I.D, Distribution and Habitat Considerations), and numerous egg and larval clusters were documented on this plant species during the 2000 season. *Plantago patagonica* occurs in dry and sandy soil, generally between 200 and 2,000 meters (656 and 6,562 feet) in elevation (Rahn 1979). This species overlaps in distribution with *P. erecta* at lower elevations, but *P. erecta* is probably more edible (less "hairy," and softer), for small pre-diapause larvae. It may be used for oviposition only when other host plant species are less available or less suitable. *Plantago patagonica* has only been documented thus far in occupied Quino checkerspot butterfly habitat where either *P. erecta* or *Antirrhinum coulterianum* also occur.

Cordylanthus rigidus (thread-leaved bird's beak), a partially parasitic plant often found at high densities in disturbed areas (Chuang and Heckard 1986), is perhaps the most widely distributed of all the primary host plants. Habitat of the plant is described as "open slopes and flats of foothill woodlands, chaparral margins, and coniferous forests" (Chuang and Heckard 1986). As noted for *A. coulterianum*, the range of the subspecies *C. rigidus setigerus* that has been documented as a primary Quino checkerspot butterfly host plant corresponds very closely with the historic range of the butterfly (Figure 2), and the Southwest California Floristic Province (Hickman 1996). However, unlike other primary host plant species, it is doubtful that *C. rigidus* could support a Quino checkerspot butterfly population in isolation from other host plants. Because it is a late-blooming hemi-parasite, it is believed by some to be too small in stature and too low in abundance early in the season to support post-diapause larval populations. *Cordylanthus rigidus* flowers in July and August (Chuang and Heckard 1986).

Plant species may be used as primary, or secondary (species of host plants consumed by larvae but not used by adults for ovipositing) hosts depending on site conditions. Other possible primary host plants include *Castilleja exserta* (owl's-clover) and other native *Plantago* species. *Castilleja exserta* is probably most important, however, as a secondary host plant (see secondary host plant discussion below). In some situations, specific combinations of host plant species should enhance habitat suitability. Various combinations of *P. erecta*, *P. patagonica, Antirrhinum coulterianum, C. exserta,* and *Cordylanthus rigidus* can be found at sites occupied by Quino checkerspot butterflies. All primary host plants for the Quino checkerspot butterfly overlap in range with others in some areas, and the presence of multiple host plant species may be an indication of habitat quality. The species of plant used for oviposition at a given site may change depending on the prevailing environmental conditions. At occupied high-elevation sites (1,219 to 1,524 meters [4,000 to 5,000 feet]) (*e.g.* the Silverado Occurrence Complex; see section I.D, Distribution and Habitat Considerations), *A. coulterianum* and *P. patagonica* co-occur. All observed eggs at the Silverado Occurrence Complex were laid on *P. patagonica* in 2000, and on *A. coulterianum* in 2001 (Pratt 2001). *Antirrhinum coulterianum* was not recorded at the Silverado Occurrence Complex in 2000 (Pratt 2001), and may be too sparse in some years to support reproduction.

Secondary host plants may be important before and after larval diapause. Secondary host plants are important for pre-diapause larvae when the primary hosts become inedible before larvae can enter diapause. Such was the case with populations of the bay checkerspot butterfly where *Plantago erecta* was the primary host plant, but most larvae survived to reach diapause by migrating to *Castilleja exserta*. Pre-diapause larvae fed on *C. exserta* until diapause, then returned to feeding on *P. erecta* when they broke diapause in winter (Singer 1972, Ehrlich *et al.* 1975). Some populations of Quino checkerspot butterfly may also be dependent for survival on multiple overlapping primary and secondary host plant distributions. In 2001, host plant micro-patches near Barrett Junction, San Diego County, had abundant populations of *Cordylanthus rigidus* and *C. exserta* intermingled with *P. erecta*, but all the larval clusters (where oviposition occurred) were found on *C. rigidus* (Pratt 2001, A. Anderson pers. observ.). It is possible that *P. erecta* is an important post-diapause secondary host plant species at this site, because *C. rigidus* is immature and less abundant than *P. erecta* when larvae come out of diapause (Pratt 2001). At occupied sites where *P. erecta* and *P. patagonica* co-occur, *P. erecta* often dries out earlier than *P. patagonica*; therefore, *P. patagonica* may serve as a pre-diapause secondary host plant at some sites (Pratt 2001).

The two most important factors affecting the suitability of host plants for Quino checkerspot butterfly oviposition are exposure to solar radiation and phenology, (timing of the plant's development). Female Quino checkerspot butterflies deposit eggs on plants located in full sun, preferably surrounded by bare ground or sparse, low vegetation. Adult female butterflies are adept at selecting those plants that receive adequate sunshine and will remain edible the longest (Mackay 1985, Parmesan 1991, Singer 1994, Parmesan *et al.* 1995). Plants shaded through the midday hours (1100 to 1400) or embedded in taller vegetation appear to be less likely targets for oviposition, probably because of the high temperature requirements of developing larvae (Weiss *et al.* 1987, 1988; Osborne and Redak 2000). However, females have been observed depositing eggs on host plants shaded by shrubs late in the season when host plants in open areas were declining in suitability (K. Osborne, pers. comm. 2002). Primary host plants must remain edible for approximately 4 weeks after eggs are laid (2 weeks for egg maturation and 2 weeks for larval feeding; Singer 1972, Singer and Ehrlich 1979).

Euphydryas editha egg clusters typically contain 20 to 150 eggs (M. Singer, C. Parmesan, and G. Pratt, pers. comm.), only a small fraction of which are likely to survive to maturity. Destruction of eggs by predators and physical disturbance can be substantial. Even so, it would be unusual for an individual *Plantago* plant to support an entire larval cluster to diapause. Normally, pre-diapause larvae consume the plant on which they hatch, then disperse in search of new plants. The ability of pre-diapause larvae to search is limited, especially prior to the third instar. First and second instar larvae can find hosts within 30 centimeters (1 foot) of their natal host plant. By mid-third instar, larvae can travel up to 1 meter (3.3 feet) to find host plants (G. Pratt, pers. comm.). Therefore, high local host density is necessary for high larval survival rates, but most host plants should occur in sufficiently open areas with high solar exposure. When secondary hosts are nearby, the density of primary host plants that is needed may be reduced.

Euphydryas editha butterflies use a much wider range of plant species for adult nectar feeding than for larval foliage feeding. These butterflies apparently learn to alight on and find nectar in particular flower species, demonstrating some degree of nectar source constancy (McNeely and Singer, in press). *Euphydryas editha* has a short tongue and cannot feed on flowers that have deep corolla tubes or flowers evolved to be opened by bees (M. Singer, pers. comm.). *Euphydryas editha* prefers flowers with a platform-like surface on which they can remain upright while feeding (D. Murphy, G. Pratt, and M. Singer, pers. comm.). The butterflies frequently take nectar from *Lomatium* spp. (lomatium), *Muilla* spp. (goldenstar), *Achillea millefolium* (milfoil or yarrow), *Amsinckia* spp. (fiddleneck), *Lasthenia* spp. (goldfields), *Plagiobothrys* and *Cryptantha* spp.(popcornflower), *Gilia* spp. (gilia), *Eriogonum fasciculatum* (California buckwheat), *Allium* spp. (onion), and *Eriodictyon* spp. (yerba santa) (D. Murphy and G. Pratt, pers. comm.). *Salvia columbare* (chia) (Orsak 1978; K. Osborne, pers. comm. 2001; G. Pratt, D. Murphy, pers. comm. 2001), and *Dichelostemma capitatum* (blue dicks) (K. Osborne, pers. comm. 2002) may also be used for nectar feeding. Quino checkerspot butterflies have been observed flying several hundred meters from the nearest larval host plant micro-patch to nectar sources (White and Levin 1981). However, studies of bay checkerspot butterflies found that they tended to deposit eggs on hosts that are close to, rather than farther from, adult nectar sources (Murphy 1982, Murphy *et al.* 1983).

Although habitat patch delineation may theoretically be estimated based on host plant micro-patch and nectar source distribution, and host and nectar plant density, delineation of long-term habitat patch footprints (and areas of extant larval occupancy) is difficult to estimate at any given time in the field. Plant population quality, density, and distribution change over time for a variety of reasons, and Quino checkerspot butterfly populations have evolved to respond to shifting habitat patch suitability in space and time (White and Levin 1981, Murphy and White 1984, Osborne and Redak 2000). For example, environmental conditions may not favor plant germination one season, or favor germination of other plant species, but low-density germination of host plant individuals and/or a seed bank may still result in abundant germination at a later date. Lower primary host plant density may be sufficient if secondary host plant species are present; however, feeding by herbivores, including Quino checkerspot butterfly larvae, will reduce the density of host plants, even under the best environmental conditions.

3. Climatic Effects

Lepidopterists have documented the extirpation of *Euphydryas editha* populations associated with unusual climatic events (Singer and Ehrlich 1979, Ehrlich *et al.* 1980, Singer and Thomas 1996). For example, the severe drought in northern California from 1975 through 1977 caused the apparent extirpation of 24 percent of surveyed populations of *E. editha* (Singer and Ehrlich 1979, Ehrlich *et al.* 1980). Observations and experiments suggest that the relationship between weather and survival of *E. editha* is mediated by the timing of its life cycle relative to that of its host and nectar plants (Singer 1972, Ehrlich *et al.* 1975, Boughton 2000). Phenological mismatches have been observed in southern California on several occasions when first instar larvae were found on plants that were already dying, making it highly unlikely that they would support the larvae to diapause (Parmesan, in press, K. Osborne, pers. comm. 2002, A. Anderson pers. observ. 2002). In general, weather conditions that hasten completion of a plant's life cycle relative to that of the butterfly, such as warm, cloudy weather, cause increased larval mortality (Singer 1983, Boughton 1999). Conversely, conditions that slow the completion of a plant's life cycle relative to that of the butterfly can increase larval survival. Microtopographic heterogeneity and associated microclimate heterogeneity, on a scale that allows larvae and ovipositing adults to select among sites, should help prolong occupancy of habitat patches (Singer 1972; Singer and Ehrlich 1979; Weiss *et al.* 1987, 1988; Osborne and Redak 2000).

Severe local climatic events can profoundly affect *Euphydryas editha* populations. The prolonged drought in California in the 1980's is credited as being largely responsible for near-extirpation of the Quino checkerspot butterfly (Mattoni *et al.* 1997). Similar effects were observed in the Jasper Ridge bay checkerspot butterfly metapopulation during the drought from 1976 to 1978 (Murphy and Ehrlich 1980). In a 1983 study, unusually cold temperatures combined with wet conditions were a major mortality factor for bay checkerspot butterfly pupae placed in the field (White 1986). Mortality during the pupal stage was high and variable enough to affect adult numbers and population dynamics (53 to 89 percent; White 1986). Historical accounts and precipitation records also suggest that a severe flood was at least partially responsible for extirpation of lower elevation Quino checkerspot butterfly populations in Orange County (see section I.C.5, Metapopulation Resilience). Weather may directly destroy individuals, or indirectly destroy them by increasing vulnerability to disease and predation (White 1986).

It has been hypothesized that the Quino checkerspot butterfly is probably better adapted to survive dry conditions, and has been selected to undergo multiple-year diapause more frequently than more northern subspecies of *Euphydryas editha* because the climate is generally warmer and drier and rains are less predictable (K. Osborne, pers. comm.). Nevertheless, two of the most severe droughts in recorded history appear to have primarily occurred in northern areas. The 1929 to 1934 drought in California, characterized as the "longest, most severe in the State's history" (Paulson *et al.* 1989) does not appear to have affected Quino checkerspot butterfly populations, and is not reflected in the Los Angeles rainfall record (A. Anderson *in litt.* 2003). The 1975 to 1977 drought that apparently contributed to extirpation of local bay checkerspot butterfly populations was characterized as "Statewide, except southwestern deserts," and "The driest 2 years in State's history, most severe in northern 2/3 of state," (Paulson *et al.* 1989). The 1975 to 1977 drought was not reflected in San Diego County rainfall records; furthermore, it immediately preceded the Quino checkerspot butterfly population explosions in southwestern San Diego County documented in the late 1970's (Murphy and White 1984). Therefore, any conclusions regarding enhanced ability of the Quino checkerspot butterfly to survive drought compared to other subspecies of *E. editha* (*e.g.* as an explanation for Parmesan's 1996 results) must be considered speculative.

4. Population Structure

Distribution of the Quino checkerspot butterfly, and many other subspecies of *Euphydryas editha*, is patchy at several geographic scales (Hanski 1999). Local resources are unevenly distributed on the scale of meters, clusters of host plant micro-patches are unevenly distributed to form habitat patches at the scale of kilometers, and these in turn are patchily distributed at even larger scales to form networks of connected habitat patches called metapopulations. Butterfly metapopulations may belong to larger interdependent networks forming greater metapopulations (Murphy and Ehrlich 1980, termed "megapopulations" by Hanski 1999).

Interaction of individuals among local habitat patch populations in a metapopulation is reduced compared to interaction within local populations. Individuals interact among local populations enough to reduce the extinction probability of the metapopulation compared to the extirpation probability of any local population (extirpation probabilities are not independent). In this case, interaction specifically refers to emigrants re-colonizing neighboring habitat patches where the local population has been extirpated, not just occasional exchanges of genetic material. Metapopulations differ from pan-mictic (well-mixed) populations with patchily-distributed habitat in that exchange of adult individuals between larval habitat patches is relatively restricted on a seasonal basis, but frequent enough that vacant habitat patches are likely to be recolonized in ecological time (Hanski 1999). All individuals in pan-mictic populations are assumed to interact equally. The pan-mictic and metapopulation models form two extremes of a continuum (Hanski 1999), with most butterfly populations probably lying somewhere in between.

Local habitat patches in *Euphydryas editha* populations are generally composed of a set of larval host plant "micro-patches" within the typical flight range of the adult butterflies (about 50 to 200 meters [160 to 660 feet]), thus comprising a greater adult "habitat patch." To estimate the amount of food resources necessary to maintain a local population, we assumed that a population of 100 adults, with a balanced sex ratio, is typical within a habitat patch. Life-history data from the field (Singer 1972, Moore 1989) indicate that in a population that is neither increasing nor decreasing, each mated female would produce, on average, three to four adults, some of which would emigrate or fail to reproduce. If a mated female lays three to four egg clusters, then each egg cluster would generate, on average, a single adult. Based on these assumptions, in a population of 100 adults, 50 females would each need to find 3 to 4 micro-patches of host plants, so a local habitat patch would need 50 x (3 to 4), or 150 to 200 suitable micro-patches of 20 (or more) *Plantago erecta* plants to support a local population of prediapause larvae. Lower density of *Plantago* spp. host plants may be sufficient if other host plant species are present.

Larger host plant “micro-patches” could accommodate more egg clusters, but no evidence exists to suggest that *Euphydryas editha* butterflies spatially distribute egg masses in a manner that would maximize offspring survival. On the contrary, individual females often apparently independently select the same oviposition sites, leading to high mortality of larvae from competition (Rausher *et al.* 1981, Boughton 1999).

Each successful post-diapause larva consumes several hundred *Plantago* seedlings, and the impact on a plant population can be severe. Therefore, post-diapause larval feeding has three consequences for habitat assessments: 1) *Plantago* density estimates made during seedling stages, when post-diapause larvae have not yet finished feeding, must consider future post-diapause feeding needs; 2) the number of observable/detectable plants in a *Plantago* population that currently supports Quino checkerspot butterfly larvae will be lower than the number in the same population without the butterflies; and 3) measurements of *Plantago* density in habitat patches not supporting larval development may overestimate the ability of habitat patches to support a butterfly population. Also, if many larvae re-enter diapause during dry years, habitat suitability with respect to required host plant density may be underestimated due to low germination rates that do not affect the population of larvae. Note, a substantial amount of primary or secondary host plants must remain after the post-diapause larvae have finished feeding if a habitat patch is to support clusters of pre-diapause larvae. If too few primary host plants remain, females must disperse to seek new habitat patches for oviposition.

Local habitats alone are generally not sufficient to ensure the long-term persistence of butterfly metapopulations (Hanski 1999). A local population may be expected to persist on the time scale of years. Persistence for longer terms (decades) derives from the interaction between sets of local habitat patch populations at larger geographic scales. These sets of populations are known as metapopulations. For the bay checkerspot butterfly, a metapopulation was described as: "...a set of populations (*i.e.*, independent demographic units; Ehrlich 1965) that are interdependent over ecological time. That is, although member populations may change in size independently, their probabilities of existing at a given time are not independent of one another because they are linked by processes of extirpation and mutual recolonization, processes that occur, say, on the order of every 10 to 100 generations." (Harrison *et al.* 1988).

The ability and propensity of larvae to undergo multiple-year diapause in the field, and survival rates during repeated diapause (currently unknown), will also affect the persistence time of local populations.

The timescale of extirpation and recolonization depends on the population's geographic/temporal scale (hierarchical level) in question (Table 1). Smaller metapopulations, composed of sets of local habitat patches described above, should persist over the course of many decades, with habitat patches recolonized within a few years to more than a decade of extirpation (Harrison *et al.* 1988). Larval occupancy blinks in and out within the habitat patches, but the metapopulation as a whole remains resilient, provided extirpations offset recolonizations. An example of a small bay checkerspot butterfly metapopulation occurs at Jasper Ridge, San Mateo County. As stated above, at larger geographic scales, sets of small metapopulations can be nested within larger "megapopulations" (Hanski 1999). Small metapopulations experience extirpation and recolonization at the megapopulation scale over the course of

Table 1. Distribution Scales of Bay Checkerspot Metapopulations.

	Habitat patch	Metapopulation	Megapopulation
Example	Area H	Jasper Ridge	Morgan Hill and associated metapopulations
Estimate of example area	less than 25 hectares (0.10 square mile)	25-400 hectares (0.10-1.5 square miles)	400-40,000 hectares (1.5-150 square miles)
Estimated number of individuals	50-500	500-2,000	over 2,000
Estimated persistence time	Years	Decades	Centuries

centuries rather than decades. However, long-term persistence of species with metapopulation dynamics may depend on maintenance of geographically intermediate habitat patches or rare long-distance dispersal events that link larger metapopulations.

Rare examples exist of *Euphydryas editha* populations that apparently do not require a metapopulation structure for long-term persistence. One example is the small *E. editha* population at Surf, north of the City of Santa Barbara near Point Sal. This local coastal population has persisted in apparent isolation for more than 50 years in a habitat patch no larger than 30 square meters (320 square feet) (Parmesan 1996), perhaps due to the stable marine climate influence. In contrast, the size of the mainland habitat patch supporting the most stable local population of the Morgan Hill metapopulation of bay checkerspot butterfly is approximately 17 by 3 kilometers (11 by 2 miles), a large geographic area (Harrison et al. 1988). In Colorado, diffuse, well-mixed populations of *E. editha* have been documented that inhabit many square kilometers of more or less continuous habitat (Ehrlich and Murphy 1987). Several metapopulations of butterfly species in Finland closely related to the Quino checkerspot butterfly (*Euphydryas aurinia, E. maturna, Melitaea cinxia, M. diamina,* and *M. athelia*) were documented to have Levin's-style population structures (see below), and all occupied distributions were close to 1,500 by 1,500 kilometers (930 by 930 miles) in size, and composed of 12 to 20 local populations (Wahlberg *et al.* 2002). At a population scale, habitat may support similar densities of *E. editha* in pan-mictic populations compared to metapopulations, but at a habitat-patch/local population scale densities may be greater for metapopulations.

Three theoretical types of metapopulation structure have been described: the mainland-island, source-sink, and Levin's types (Hanski 1999). The bay checkerspot butterfly metapopulation at Morgan Hill represents an example of a mainland-island type in which occupancy of a single, large mainland habitat patch persists through time while outlying small island habitat patches must be regularly recolonized (Harrison *et al.* 1988). This population structure is similar to the one Murphy and White (1984) hypothesized exists for the Quino checkerspot butterfly in the Otay Lakes area, San Diego County. A mainland-island metapopulation contains one or more very large habitat patch/population (the mainland) with a lower risk of extirpation, and other, smaller (island) habitat patches/populations with higher risks of extirpation than the mainland population due to their limited size. This type is slightly different from the “source-sink” population model (below), in that island populations can have the same growth rates as the mainland patch. Island populations may be collectively just as important to metapopulation persistence as is the mainland population, and they are likely to serve as sources of immigration for each other, or even the mainland patch in case of catastrophic events such as wildfire.

A source-sink metapopulation contains one or more local populations that are commonly sources of colonization for associated sink populations. In source populations, emigration exceeds immigration, while in sink populations, immigration exceeds emigration. Sink populations are dependent, at least temporarily, on source populations to maintain nonnegative growth rates. It would be a mistake to assume source populations are more resilient over time, as the status of local populations can change and may even be reversed when changing environmental or density-dependent factors alter the growth rates of local populations (Boughten 1999, 2000). Even if immigration exceeded emigration in a sink, as long as sinks produce some emigrants, they may occasionally recolonize neighboring habitat patches (they are just less likely to do so than a source population).

A Levin’s-type metapopulation, as exemplified by the *Euphydryas editha nubigena* (Sierra Nevada Edith's checkerspot butterfly) metapopulation along the General's Highway in Tulare County, has a structure in which each habitat patch (except those disturbed by logging) has a more or less equal probability of extirpation (Thomas *et al.* 1996). Not all local populations are extirpated simultaneously, and patches supporting larval development regularly provide immigrants for habitat patches temporarily not supporting larvae (Singer and Thomas 1996; Thomas *et al.* 1996; Boughton 1999, 2000). It is possible for a metapopulation structure to exhibit aspects of all three types. It is not known which type of metapopulation structure is most common in the Quino checkerspot butterfly, but most populations of this species almost certainly have an element of metapopulation structure at some geographic and spatial scale.

Using metapopulation theory, reserves should be designed to provide sufficient numbers of habitat patches such that: 1) only a small number of habitat patches will likely be extirpated in a single year; and 2) patches are close enough that natural recolonization can occur at a rate sufficient to maintain a relatively constant number of patches supporting larval development. In general, the more frequent the extirpations, the more patches that are necessary to support a metapopulation for a given length of time (Harrison and Quinn 1989). Environmental diversity among member habitat patches should also reduce the probability of simultaneous extirpation of habitat patches (Harrison and Quinn 1989). Landscape connectivity between and within metapopulations should be maintained whenever possible.

Fragmentation of Quino checkerspot butterfly habitat has isolated many habitat patches and small networks from other habitat patches and networks, therefore the need for active future management is anticipated. Extirpation of isolated local populations is likely, given that periodic extirpations on that scale is common in *Euphydryas editha* (Ehrlich *et al.* 1975). All else being equal, the probability of a small metapopulation being extirpated within a few decades is higher than a larger one because of the increased probability of simultaneous extirpation of each habitat patch. Unless a resilient mainland population is documented, Quino checkerspot butterfly reserves should be designed to protect presumed Levins-style metapopulation dynamics, in which a relatively constant number of linked habitat patches occupied by larvae persist and natural extirpation and recolonization of all local populations occurs with equal frequency.

The scientific literature commonly refers to habitat patches within a metapopulation as “occupied” or “unoccupied,” depending on whether they support larval development, and adult use is detectable. However, to avoid confusion between the metapopulation scale use of the term occupancy, and the habitat patch/local population scale use of this term, in this document we avoid referring to habitat patches within the current distribution of a metapopulation as unoccupied. Although local populations, may be “extirpated,” and habitat patches may be recolonized, all habitat patches within a metapopulation distribution are considered to be occupied by adults. If a population is well-mixed, then the “habitat patch” defines its distribution, and the term “occupancy" is used.

5. Metapopulation Resilience

The term resilience is used here to describe persistent Quino checkerspot butterfly populations. Although no quantitative analysis of a model to fit Quino checkerspot butterfly population dynamics is possible at this time, populations do appear to fit the qualitative description of a resilient system. Resilient natural systems tend to maintain their integrity when subject to disturbance; examples include periodic insect population outbreaks resulting from a hard loss of stability (resistance to restabilization) and hysteresis (presence of a lag-time prior to effect observation) (Ludwig *et al.* 1997). Although resilient populations may naturally show great fluctuations in size, they are capable of maintaining the their integrity over time if suitable habitat remains available.

Local Quino checkerspot butterfly populations that survive such negative environmental events as prolonged drought appear to have the potential to rapidly increase in density and recolonize habitat patches under favorable conditions. This ability is characterized by rapid increases in density and then dispersal to habitat patches not currently supporting larval development when natal patches become too densely occupied (Harrison 1989, Murphy and White 1984). Dispersal events primarily serve to recolonize habitat patches where local populations were extirpated by catastrophic events such as fire, by prolonged unfavorable environmental conditions, by stochastic population events, or by density-dependent intra-specific competition. Single and multiple-year diapause allows local populations to persist short-term (1 or more years) in habitat patches when environmental conditions remain unfavorable for less prolonged periods (maximum number of years unknown). This combination of population-regulation mechanisms has been termed "density-vague," where both density-dependent and environmental factors contribute to long-term population dynamics (Strong 1986).

There appears to be a delicate balance between the ability of Quino checkerspot butterfly populations to survive detrimental environmental conditions and rapidly increase in number under favorable conditions, and their vulnerability to habitat destruction and adverse environmental conditions (Murphy and White 1984). In the past the Quino checkerspot butterfly has exhibited population outbreaks (Orsak 1974, Murphy and White 1984) and these outbreaks have, in some cases, been followed by population extirpation (Orsak 1974). Environmental conditions that would naturally result in a temporary population crash followed by recovery, may result in extirpation of the population when their effects are exacerbated by human impacts to habitat.

Accounts of large population density fluctuations at historic Quino checkerspot butterfly population sites (Orsak 1973, Murphy and White 1984), and collection record data (A. Anderson *in litt.* 2003), indicate that the Quino checkerspot butterfly is a climate-sensitive, "eruptive" species that semi-regularly increases its adult densities by orders of magnitude over a period of 5 to 10 years, then drops back to much lower densities over a similar period of time (Orsak 1974, A. Anderson *in litt*. 2003). Droughts, fires, and floods appear to severely reduce population densities, but intermediate amounts of precipitation, combined with high temperatures, appear to restore high population densities (Murphy and White 1984, A. Anderson *in litt.* 2003). These major weather pattern-driven fluctuations in Quino checkerspot butterfly population densities are similar to the long-term population fluctuations in the bay checkerspot butterfly recorded by Paul Ehrlich's research group at Jasper Ridge (Ehrlich *et al.* 1975). The balance between resilience and vulnerability appears to have been disrupted in this case, because the Jasper Ridge bay checkerspot butterfly population is believed to have been extirpated in 1997 (Mattoni *et al.* 1997). The last range-wide Quino checkerspot butterfly population density and/or distribution low was in the late 1980's. Other documented historic range-wide density and/or distribution lows for this species occurred in the mid 1960's, early 1950's, the late 1930's-early 1940's, and the mid-1920's (A. Anderson *in litt.* 2003). The Quino checkerspot butterfly appears to exhibit population lows about every 10 to 20 years corresponding with either drought or flood conditions (A. Anderson *in litt.* 2003). Increased late 1990's/early 2000's population levels (relative to the 1980's) were certainly reduced relative to past levels (pre-1980's) due to extensive, cumulative habitat and population loss caused by humans. If past patterns and the severe "100-year" 2002 drought (National Climatic Data Center 2002) are any indication, we may experience another decline over the next 5 years. It is not clear that the remaining populations are resilient enough to survive another decline such as the one that occurred in the 1980's.

The apparent extirpation of the Quino checkerspot butterfly from Orange County is probably an example of a large-scale loss of populations and regional resiliency (megapopulation extirpation). Examination of the history of Orange County Quino checkerspot butterfly populations (A. Anderson *in litt*. 2003) indicates that a combination of naturally occurring events (*e.g.* drought, cold-snaps, flood, and fire), exacerbated by ongoing human-caused habitat destruction and degradation (development, agriculture, and grazing), resulted in the apparent extirpation of formerly resilient Quino checkerspot butterfly populations from Orange County. In 1938, a 100-year flood (Paulson *et al.* 1989) apparently eliminated what was left of the low-elevation Quino checkerspot butterfly populations in Orange County (A. Anderson *in litt.* 2003) and marked the last year of any recorded lower-elevation Quino checkerspot butterfly collection in Orange County (A. Anderson, *in litt.* 2003). The severity of this flood was described as:

> ...some of the heaviest rain ever recorded occurred in 1938. A storm hit February 27 and did not subside until five days later. Ten inches fell on the fourth day alone, at times measuring two inches an hour. Roads and bridges were washed out and 19 people drowned (Orange County Water District 2001).

If the lower elevation population of the butterfly that existed at Irvine Park, Orange County, had not been permanently extirpated, apparently by a combination of human-related impacts and catastrophic natural events, it probably would have served as a source of recolonization for the higher-elevation Black Star Canyon/Hidden Valley population (approximately 5 kilometers [3 miles] away) after the 1967 fire that apparently extirpated that population. Conversely, if most of the habitat at Irvine Park had not been degraded, higher elevation populations might have recolonized that habitat following the 1938 flood event.

On the scale of the species-wide distribution of the Quino checkerspot butterfly (and in most cases on the population scale as well), each consecutive population density high and low during the 20th century must have been reduced from the previous one, due to ongoing human-caused destruction of habitat and source populations. This undeniable long-term downward population trend, superimposed on apparent 10- to 20-year population density peaks, must be considered when assessing current species' status and planning for recovery. For some recovery units, we may be approaching an extirpation threshold in the long-term population density and distribution decline, the threshold where the cycle is disrupted and resilience is lost, but that may not be apparent for 5 or more years.

It has been over 10 years since the drought of the 1980's ended, and rainfall has been relatively abundant in the 1990's (A. Anderson *in litt.* 2003), indicating we may have reached the latest 10- to 20-year population density and distribution peak in southern San Diego County. However, Quino checkerspot butterfly densities remain far below what they were in the late 1970's (D. Murphy, M. Singer, pers. comm.). Dispersal and recolonization events were probably high during the 1999 season because it was a relatively dry year preceded by a wet year (Murphy and White 1984, Anderson 2000, A. Anderson *in litt*. 2003). It is likely that there will be yet another drought-induced Quino checkerspot butterfly crash during the next 5 to 10 years, such as the ones that occurred in the 1980's and during the 1960's (A. Anderson *in litt*. 2003). Without intervention such a crash would be likely to result in extirpation of populations as apparently happened in Orange County and the Rancho Santa Fe/Lake Hodges area, San Diego County (A. Anderson *in litt.*). Recent evidence supports Murphy and White's (1984) hypothesis:

> The extirpation of a single, large reservoir population of [Quino checkerspots] may effectively deny other habitats necessary migrants, creating a ripple effect of irreversible long-term extinctions. We suspect that just such a circumstance has eliminated *Euphydryas editha* [*quino*] from Orange County and much of coastal San Diego County, and now threatens populations in Riverside and inland San Diego Counties in California.

Unfortunately we do not yet know how much local Quino checkerspot butterfly density, distribution, and habitat availability can be reduced without critically compromising the species' resiliency, but we are likely approaching that threshold in some areas. Even in cases where a species has been historically resilient and has had a high reproductive capacity under favorable conditions, it is still possible for human alteration of crucial habitat elements in the right places at the right time to cause its extinction (Lockwood and Debray 1990). Therefore, despite the discovery of new occupied sites from 2001 through 2003, it remains crucial that as many habitat patches as possible (regardless of known occupancy) be conserved, restored, and managed, and that we attempt to maintain all populations that can feasibly be managed for resilience.

D. Distribution and Habitat Considerations

The Quino checkerspot butterfly was historically distributed throughout the coastal slope of southern California, including Los Angeles, Orange, western Riverside, San Diego, and southwestern San Bernardino Counties (Figure 2), and northern Baja California, Mexico (Mattoni *et al.* 1997). The Quino checkerspot butterfly's distribution included the westernmost slopes of the Santa Monica Mountains, the Los Angeles Plain and Transverse Ranges to the edge of the upper Anza-Borrego desert, and south to El Rosario in Baja California, Mexico (Emmel and Emmel 1973, Mattoni *et al.* 1997). Although historical collection records permit estimation of a species' range, such records usually underestimate the number of historical sites and extent of regional distributions. Butterfly collectors tended to frequent well-known sites, and no systematic or comprehensive surveys for the Quino checkerspot butterfly have ever been conducted (Mattoni *et al.* 1997). Multiple observations of Quino checkerspot butterflies have been reported across a wide elevation range, from approximately 153 meters (500 feet) in elevation to over 1,533 meters (5,000 feet).

As recently as the 1950's, collectors described the Quino checkerspot butterfly as occurring on every coastal bluff, inland mesa top, and lower mountain slope in San Diego County and coastal northern Baja California (D. Bauer, pers. comm.). These observations indicate that the Quino checkerspot butterfly was historically widespread throughout the southern California landscape and occurred in a variety of vegetation types, including coastal sage scrub, open chaparral, juniper woodland, forbland, and grassland communities. By the 1970's, most of the coastal bluff and mesa habitats in southern California had been urbanized or otherwise disturbed. However, the butterfly still occupied known habitat locations inland and at higher elevations including Dictionary Hill, Otay Lakes, and San Miguel Mountain in San Diego County, and the Gavilan Hills in Riverside County (U.S. Fish and Wildlife Service 1997a). By the mid-1980's, the species was thought to have disappeared from all remaining locations; the petition to list the species in 1988 suggested that it might be extinct (U.S. Fish and Wildlife Service 1997a). Nonetheless, new populations were discovered in Riverside County, the butterfly was rediscovered in San Diego County, and it continued to survive in northern Baja California, Mexico (Parmesan 1996). Current information suggests that the butterfly has been extirpated from Los Angeles, Orange, and San Bernardino Counties (Figure 2). Most California populations of the butterfly probably occur in degraded, marginal habitat on the periphery of historic metapopulation centers (Parmesan 1996; D. Murphy, pers. comm.).

Extant Quino checkerspot butterfly populations primarily inhabit grassland, remnant forbland, juniper woodland, and open scrub and chaparral communities that support the primary larval host plants and a variety of adult nectar resources. These areas tend to be distributed as patches in a mosaic of vegetation communities. A recent larval microhabitat use study indicated that patches of exposed soil with abundant solar exposure and host plants, combined with interspersed shrub cover and topographic heterogeneity, provides additional long-term resilience to Quino checkerspot butterfly populations (Osborne and Redak 2000). Habitat patch suitability is determined primarily by larval host plant density, topographic diversity, nectar resource availability, and climatic conditions (Singer 1972, Murphy 1982, Weiss *et al.* 1988, Murphy *et al.* 1990). In combination, these varying habitat features result in extremely localized butterfly population density fluctuations and periodic local population extirpation and recolonization events within patches of habitat (Ehrlich 1965).

Although environmental variation among occupied habitats has made it difficult to identify habitat indicator plant species, several species that frequently co-occur with the butterfly's host plants and Quino checkerspot butterfly populations are worth mentioning (Pratt 2001). The annuals *Lepidium nitidum* (peppergrass), *Layia platyglossa* (tidy-tips), *Lasthenia californica* (goldfields), *Crassula connata* (pygmy weed), and *Hemizonia* sp. (tarplant) are commonly found on occupied habitat. Bulb species such as *Dichelostemma capitatum* (blue dicks), *Fritillaria biflora* (chocolate lilies), and *Zigadenus fremontii* (star lilies) are also known from occupied habitat. *Hemizonia* may be a good field reference for clay lens habitat because it forms dense stands visible at great distances long after senescence. *Dudleya multicaulis* (many-stemmed dudleya) and *Dudleya variegata* (variegated dudleya) are also clay soil indicators. *Eriogonum fasciculatum* (California buckwheat) has been found in all occupied Quino checkerspot butterfly habitat documented to date (Pratt 2001). *Acarospora schleicheri* (a thick yellow lichen) and *A. thelococcoides* (a cream white, donut-shaped lichen) are commonly associated with cryptogamic crusts in occupied Quino checkerspot butterfly habitat. *Acarospora thelococcoides* is rare in southern California. Above 920 meters (3,000 feet) in elevation *Selaginella* *bigelovii* (spike-moss) is more commonly associated with soil crusts than lichens. Although *E. fasciculatum* is very common throughout southern California, its absence could be an important indicator of Quino checkerspot butterfly absence (Pratt 2001).

Disturbances that have compromised Quino checkerspot butterfly metapopulation integrity include conversion of habitat by development or vegetation-type changes, grazing, trampling, fragmentation of habitat, and reduction or severing of the landscape connectivity that facilitates habitat patch recolonization. Linkage of suitable habitat patches by adult dispersal areas (landscape connectivity) is crucial to metapopulation resilience. Dispersal areas should connect as many habitat patches as possible to facilitate metapopulation dynamics (Thomas 1994). Habitat patches that have fewer and/or longer dispersal area connections to other patches, all else being equal, have lower probabilities of natural recolonization events following local extirpation. Based on the results of Harrison *et al.* (1988) and Harrison (1989), dispersal areas greater than 2 kilometers (1.2 miles) distant do not appear likely to be used by adult bay checkerspot butterflies belonging to the same metapopulation. By definition, dispersal areas do not support larval host plants in densities sufficient to be considered habitat, but may support nectar sources used by dispersing adult butterflies. Dispersal areas should be free of presumed dispersal deterrents (*e.g.*, large artificial structures) and mortality sinks (*e.g.* high-traffic roads).

Simply protecting occupied habitat from direct destruction by agricultural or urban development and grazing will not be sufficient to protect resident populations (see section I.C.4, Population Structure). Rural lands that are infused with or surrounded by development experience direct and indirect human-caused disturbance including trampling, off road vehicle use, dumping, pollution, and enhanced nonnative species invasion, all of which reduce population resilience. Protected areas larger than habitat patch boundaries are needed within the long-term distribution of a metapopulation (often referred to as the metapopulation "footprint" [*e.g.* Launer and Murphy 1994]) to conserve landscape-level habitat integrity. The need to protect habitat from indirect effects of nearby or intruding development is evidenced by the apparent extirpation of local populations in the Lake Hodges and Dictionary Hill areas, where Quino checkerspot butterflies have not been recorded since the 1980's (Figure 2), despite focused efforts to find them (Caltrans 2000; City of San

Diego 2000; Faulkner 1998; G. Pratt, pers. comm. 2001; D. Faulkner and K. Williams, pers. comm.). The Lake Hodges and Dictionary Hill butterfly population sites were within large, primarily undeveloped areas with historical records indicating long-term stable occupancy prior to isolation by development (Figure 2). Habitat suitability may be conserved by preservation of undeveloped land between areas of development and habitat or by costly perpetual management to control human traffic, prevent repeated nonnative species invasions, and other measures such as augmentation of butterfly populations.

Spatially clustered Quino checkerspot butterfly observations are called occurrence complexes in this recovery plan; the largest ones (in area or number of reported individuals) are termed "core occurrence complexes". Occurrence complexes represent current short-term documented local occupancy, probably within the greater distribution of extant metapopulations. Occurrence complexes are mapped using 1-kilometer (0.6-mile) movement radii. This distance delineates the area within which we would expect to find the habitat associated with the observed butterfly (Gilbert and Singer 1973, Harrison *et al.* 1988, Harrison 1989). Occurrences within 2 kilometers (1.2 miles) of each other are considered to be part of the same occurrence complex because such observations are proximal enough that the observed butterflies are likely to have come from the same population (Ehrlich and Murphy 1987, Harrison *et al.* 1988, Harrison 1989). Population distributions (not yet fully described) may include more than one occurrence complex and metapopulation distributions are likely to be greater than the distribution of most occurrence complexes. Core occurrence complexes may represent current population density centers. Further research is required to determine the specific population distributions required for resilience. The distribution of the Quino checkerspot butterfly across its range is described in more detail below, organized geographically by habitat regions based on unique components of habitat suitability essential to Quino checkerspot butterfly protection and recovery. Habitat considerations described in this section are largely drawn from the personal observations of the authors, and examination of GIS data and aerial photography.

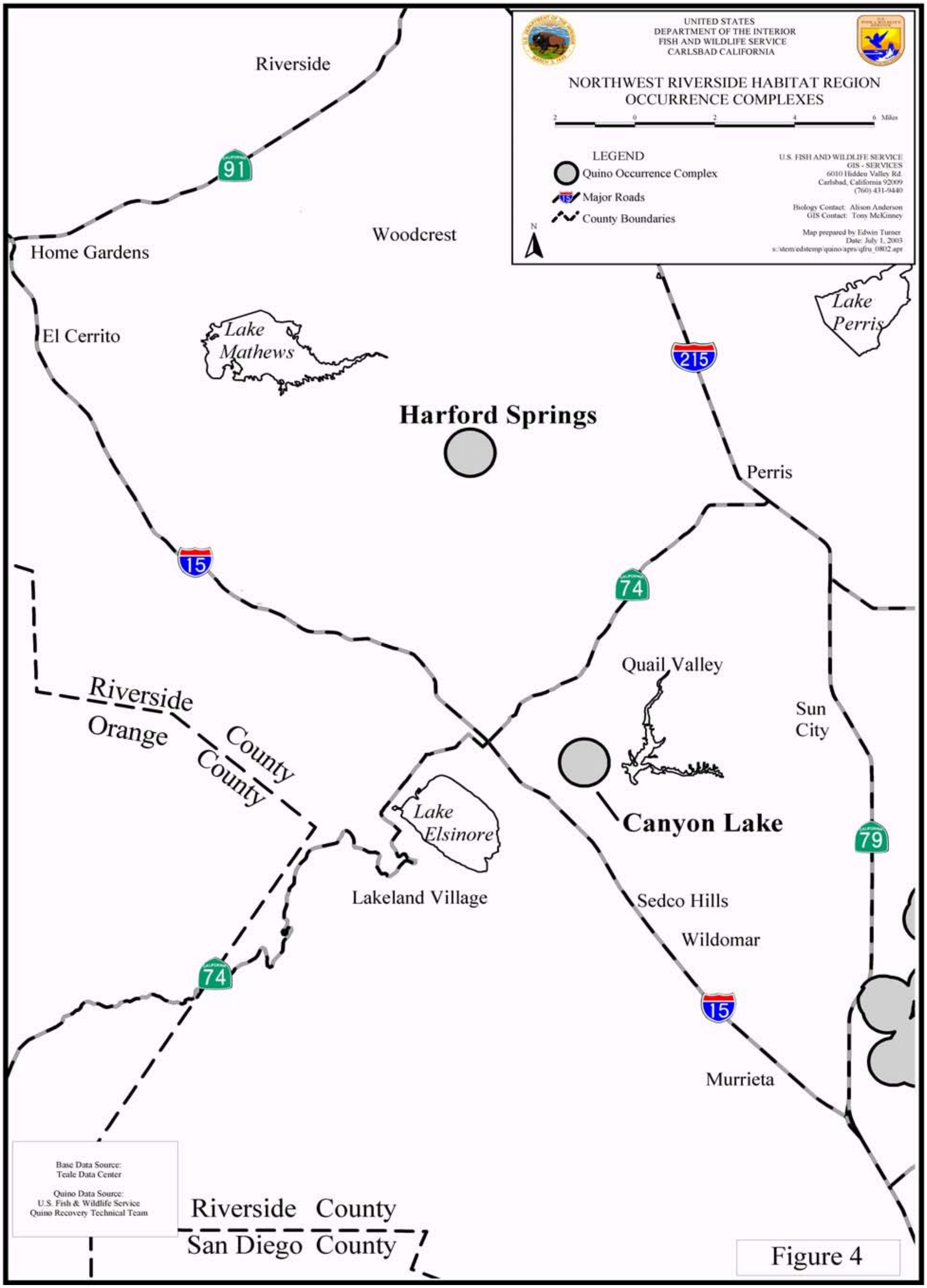
1. <u>Northwest Riverside County Habitat Region</u>

Harford Springs and Canyon Lake Occurrence Complexes, and Lake Mathews population site (Figure 4):

One Quino checkerspot butterfly larva was observed in Harford Springs County Park, Riverside County, in 1998. This site was once part of a more extensive, well documented distribution south and east of Lake Matthews, Riverside County (Figure 2). Adult Quino checkerspot butterflies were last observed south of Lake Mathews in 1985 (Figure 2). The Quino checkerspot butterfly was historically abundant in this "Gavilan Hills" area, with consistently high densities reported from the Harford Springs area (called "Lilly Hill") by collectors from the 1950's to the mid-1980's (Orsak 1978; K. Osborne and G. Pratt, pers. comm. 2000). Other recent Quino checkerspot butterfly observations were reported at two sites near the intersection of Clinton Keith Road and Interstate 15 (Figure 2), however, these habitat areas were highly degraded and considered to be isolated, and were subsequently authorized for development. In 2002, a Quino checkerspot butterfly was observed just north of the intersection of Interstate 15 and Railroad Canyon Road (Canyon Lake Occurrence Complex, Figure 4). This observation confirms continued occupancy of habitats in the vicinity of Lake Elsinore and Canyon Lake, as suggested by 1980's observations north of Lake Elsinore (Figure 2).

Habitat Considerations:

This habitat region is generally located in northwestern Riverside County, west of Interstate 215, and south of Lake Mathews. These habitats typically support abundant *Plantago erecta* on exposed soil patches. Currently and formerly occupied sites exhibit diverse vegetation types, remnant forbland, grassland, coastal sage scrub, and open juniper woodlands. Quino checkerspot butterfly occupancy is often associated with clay soils in this region, but cryptogamic crusts have become rare. *Plantago erecta* is the primary host plant found in this region, but there are some *Antirrhinum coulterianum* records as well (Thompson 1988).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NORTHWEST RIVERSIDE HABITAT REGION
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GIS - SERVICES
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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
s:/stem/edstemp/quino/aprs/qfru_0802.apr
Riverside
91
Home Gardens
Woodcrest
El Cerrito
Lake Mathews
Lake Perris
215
Harford Springs
Perris
15
74
Quail Valley
Sun City
Riverside County
Orange County
Canyon Lake
Lake Elsinore
79
Lakeland Village
Sedco Hills
Wildomar
74
15
Murrieta
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Riverside County
San Diego County

Figure 4

The Gavilan Hills area south and east of Lake Mathews is characterized by high-quality habitat patches with dense, extensive stands of *Plantago erecta* in juniper woodland, coastal sage scrub, and grassland. Landscape connectivity still exists between Harford Springs County Park and Lake Mathews, and apparently suitable habitat containing dense stands of *P. erecta* exists south of Lake Mathews in the vicinity of Black Rocks, west of Monument Peak (K. Osborne, pers. comm.). Stands of plantain also occur in the vicinities of Estelle Mountain, Railroad Canyon Reservoir, and the town of Sun City (A. Anderson, pers. observ. 2001). It is possible that the Black Rocks habitat patch was a historical source of butterflies for other habitat patches in the area (K. Osborne, pers. comm. 2000). Possibly suitable habitat and abundant host plants are found in coastal sage scrub and remnant forblands in the vicinity of Canyon Lake, particularly on Bureau of Land Management-administered lands to the north (Kabien Park and environs) (G. Pratt, pers. comm. 2000, A. Anderson, pers. observ. 2001).

Although much habitat remains in the region that appears to still be suitable, degradation of the most well-document historic sites was evident. Observations in 2001 of formerly suitable habitat revealed pervasive habitat degradation problems at the historic collection site known as Lily Hill adjacent to Harford Springs Park. This area is privately owned. Observations of Lilly Hill from Gavilan Road and from Harford Springs Park (where larvae were observed in 1997) in 2001 revealed high levels of disturbance, indicative of recent off-road-vehicle use and possibly discing. There was also a considerable amount of refuse dumping that had occurred in the surrounding juniper woodlands. Scattered *Zigadenus fremontii* plants could still be observed from a distance, but based on current habitat conditions, it is unlikely that Quino checkerspot butterfly populations remain in the vicinity of Lily Hill, outside of Harford Springs Park (A. Anderson, K. Cleary-Rose, pers. observ. 2001). Type conversion of native habitat to exotic grassland at historic collection sites was observed within the Lake Mathews Population Site, just south of the western end of Lake Matthews. Type conversion appeared to be primarily a result of past grading activity (A. Anderson, pers. observ. 2001, K. Osborne, pers comm. 2001). Despite the degraded habitat conditions described above, these sites may still be restored.

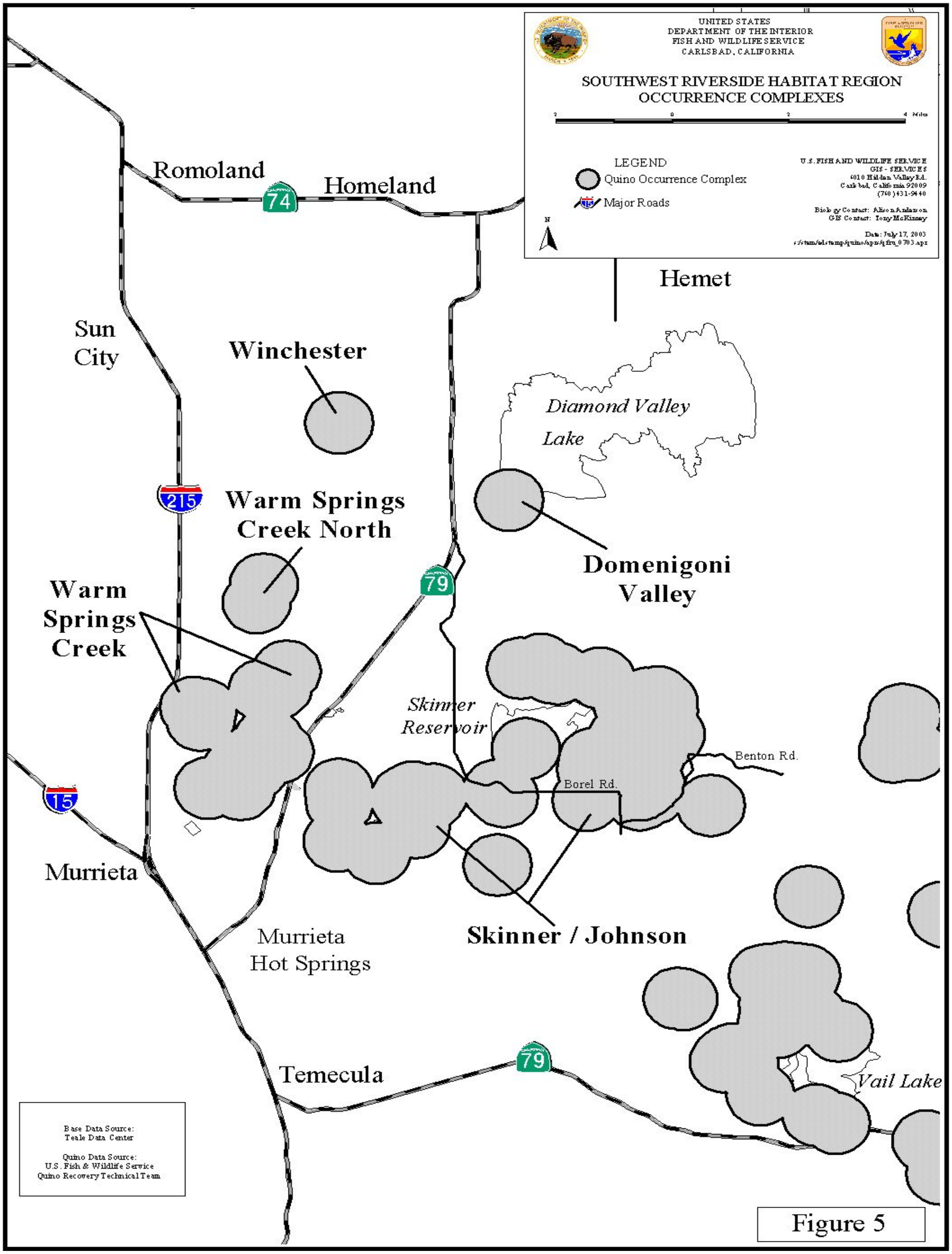
2. Southwest Riverside County Habitat Region

Warm Springs Creek (core), Warm Springs Creek North, Winchester, Domenigoni Valley, and Skinner/Johnson (core) Occurrence Complexes (Figure 5):

Recent Quino checkerspot butterfly observations west of State Route 79 are distributed between Interstate 215 and State Route 79 north of Murrieta Hot Springs Road to Diamond Valley, concentrated in the vicinity of Warm Springs Creek (Figure 2). Habitat in the Murrieta area, at the southeastern end of the Hogbacks, where butterflies were recently observed, was disced in 1998, but was still occupied in 1999 (M. Couffer pers. comm 1999). Recent Quino checkerspot butterfly observations east of State Route 79 are distributed throughout the Southwest Riverside County Multiple Species Reserve, and are concentrated around Lake Skinner and south of Benton and Borel Roads (Figure 5). Quino checkerspot butterflies have also recently been observed in the eastern portion of the City of Temecula, north and south of State Route 79, and in the hills southwest of the town of Winchester (Figure 2). In 2001, a new observation was reported southeast of Lake Skinner, extending the Skinner/Johnson Occurrence Complex east toward the Black Hills (Figure 5). A second observation in 2001 also resulted in identification of the Domenigoni Valley Occurrence Complex north of Bachelor Mountain, near the southwestern margin of Diamond Valley Reservoir (Figure 5). Most Quino checkerspot butterfly records in this region occur below 610 meters (2,000 feet) in elevation.

Habitat Considerations:

This habitat region is generally located in western Riverside County east of Interstate 215 to about 760 meters (2,500 feet) in elevation, between the town of Winchester and the City of Temecula. Quino checkerspot butterfly populations in this region are most commonly, but not exclusively, associated with low rounded hills and gentle south-facing slopes. Openings in grassland, remnant forblands, and coastal sage scrub provide habitat for the butterfly throughout most of the region. These habitats typically support scattered shrubs and abundant *Plantago erecta* on exposed clay soil patches. *P. erecta* is the primary host plant found in this region, but there are some *Antirrhinum coulterianum*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SOUTHWEST RIVERSIDE HABITAT REGION
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(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Date: July 17, 2003
Romoland
74
Homeland
Hemet
Sun City
Winchester
Diamond Valley Lake
215
Warm Springs Creek North
Domenigoni Valley
Warm Springs Creek
79
Skinner Reservoir
Benton Rd.
Borel Rd.
15
Murrieta
Skinner / Johnson
Murrieta Hot Springs
Temecula
79
Vail Lake
Base Data Source:
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Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team

Figure 5

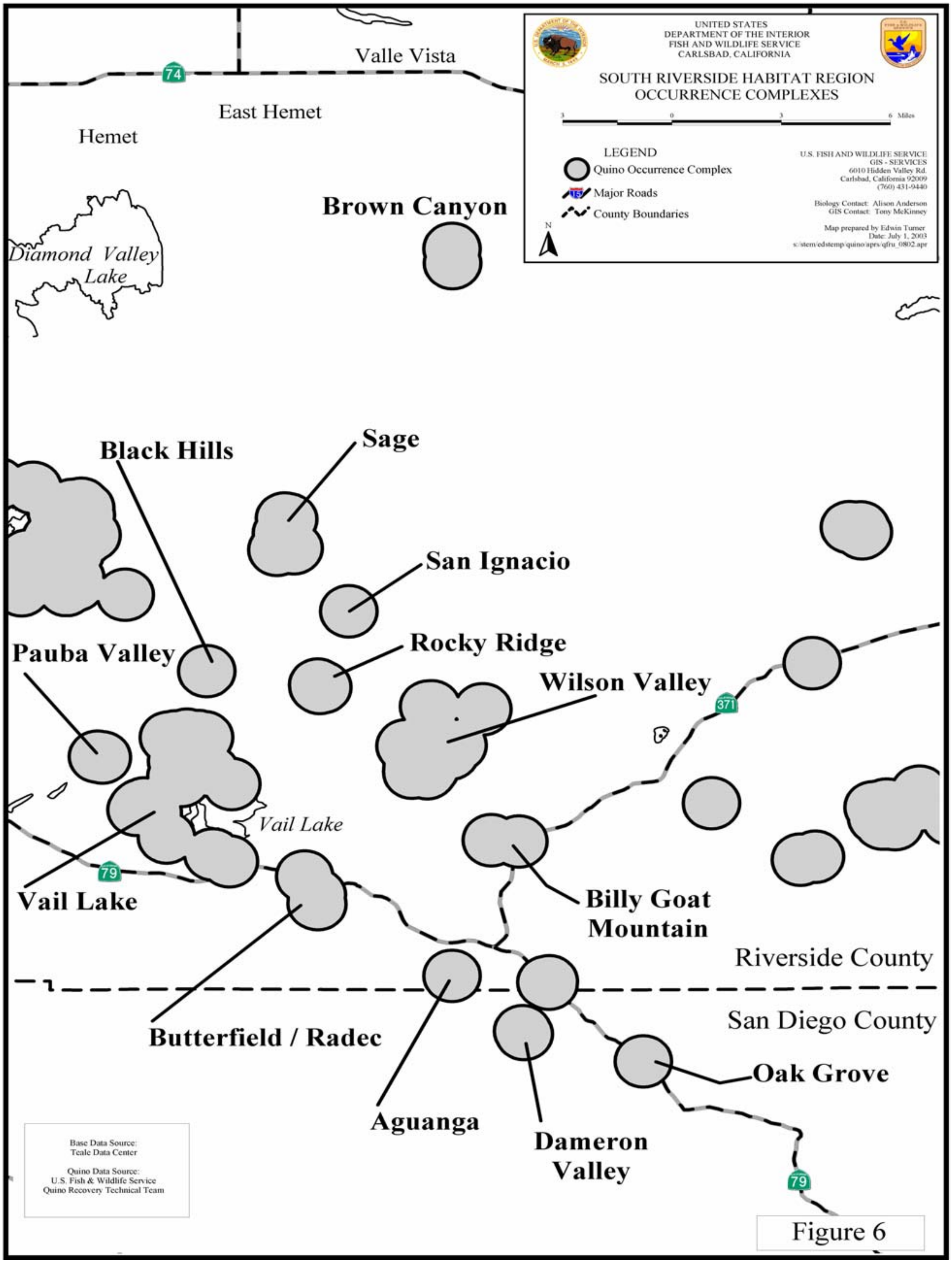
records in the region as well (Thompson 1988). In habitat surrounding Lake Skinner (Osborne 1999), dense stands of *P. erecta* and scattered *Eriogonum fasciculatum* occur on red clay lenses, surrounded by dense stands of nonnative brome and oat grasses. Habitat supporting larval development also occurs in natural inclusions in areas of encroaching development and recently or currently active agricultural land (*e.g.* Johnson Ranch).

Landscape and habitat connectivity is fragmented by agriculture and ongoing development throughout this region, with the exception of the Southwest Riverside County Multiple Species (Shipley) Reserve area. Any landscape connectivity that may have existed in the vicinity of the City of Temecula, south of the described habitat complexes (*e.g.* Crowne Hill; Figure 2) and north of Scott Road in the French Valley area has been highly compromised. Habitat in those areas is not considered important for recovery. Landscape connectivity between the Warm Springs Creek and Skinner/Johnson Occurrence Complexes has been compromised by State Route 79 and associated development. Landscape connectivity between the Skinner/Johnson and Warm Springs Creek Occurrence Complexes may need to be enhanced or artificially accomplished by ongoing butterfly augmentation efforts in order to maintain a resilient western Riverside County population of the butterfly.

<u>3. South Riverside County Habitat Region</u>

Pauba Valley, Black Hills, Vail Lake (core), Sage (core), Brown Canyon, San Ignacio, Rocky Ridge, Wilson Valley (core), Butterfield/Radec, Billy Goat Mountain, Aguanga, Dameron Valley, and Oak Grove Occurrence Complexes (Figure 6):

Recent Quino checkerspot butterfly observations are scattered throughout the lower elevation areas between the northeastern slope of Palomar Mountain, and the town of Hemet (Figure 6). Observations are concentrated in the Oak Mountain (a historic collection site), Vail Lake, and Wilson Valley areas. New observations were reported in 2001 and 2003 south of State Route 78 on the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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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Valle Vista
74
East Hemet
Hemet
Brown Canyon
Diamond Valley Lake
Black Hills
Sage
San Ignacio
Pauba Valley
Rocky Ridge
Wilson Valley
371
Vail Lake
79
Vail Lake
Billy Goat Mountain
Riverside County
San Diego County
Butterfield / Radec
Oak Grove
Aguanga
Dameron Valley
79
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U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Figure 6

northern slope of Palomar Mountain, resulting in identification of the Butterfield/Radec and Aguanga Occurrence Complexes (Figure 6). Two occurrence complexes are found in San Diego County, one in northern Dameron Valley south of State Route 79, and one farther south in Oak Grove Valley (Figure 6). In 2001, two Quino checkerspot butterfly observations were made on the Highpoint Fuelbreak above Dameron Valley, confirming continued occupancy on the northern slope of Palomar Mountain and expanding the Dameron Valley Occurrence Complex. One possibly isolated occurrence complex (Brown Canyon) is found southeast of the town of Hemet (Figure 6).

Habitat Considerations:

This habitat region is generally located between the northeastern slope of Palomar Mountain (south of State Route 79) and the town of Hemet (south of State Route 74). In this region, Quino checkerspot butterflies are generally associated with gentle south-facing slopes. Habitat primarily occurs in coastal sage scrub openings. Clay soils in the west transition into granitic soils in the east (U.S. Fish and Wildlife Service 1997). *Plantago erecta* and *P. patagonica* are the primary host plants found in this region, but there are some *Antirrhinum coulterianum* (Thompson 1988) and *Cordylanthus rigidus* (Chuang and Heckard 1986) records from this region as well. Landscape connectivity between occurrence complexes is generally good, but destruction of occupied habitat in the Vail Lake and Wilson Valley Occurrence Complexes by off-road vehicles and refuse dumping has reached a critical level (G. Pratt, pers. comm. 2001). Oak Grove Valley is highly invaded by nonnative grasses and is actively grazed at lower elevations, but much habitat appears to remain on the hills. Lands surrounding Oak Grove Valley remain relatively undeveloped, including Chihuahua Valley to the east.

Although it may be somewhat isolated from other occupied habitat, the Brown Canyon Occurrence Complex is nevertheless considered to be important for the species' recovery. The Brown Canyon Occurrence Complex is the northeastern-most complex within the current range of the butterfly, and is contiguous with the last remaining possible landscape connectivity to the northern portion of its former range. Further, the Brown Canyon Occurrence Complex has apparently been insulated from habitat impacts associated with development and recreational activities due to adjacent forested, mountainous terrain and publicly owned lands.

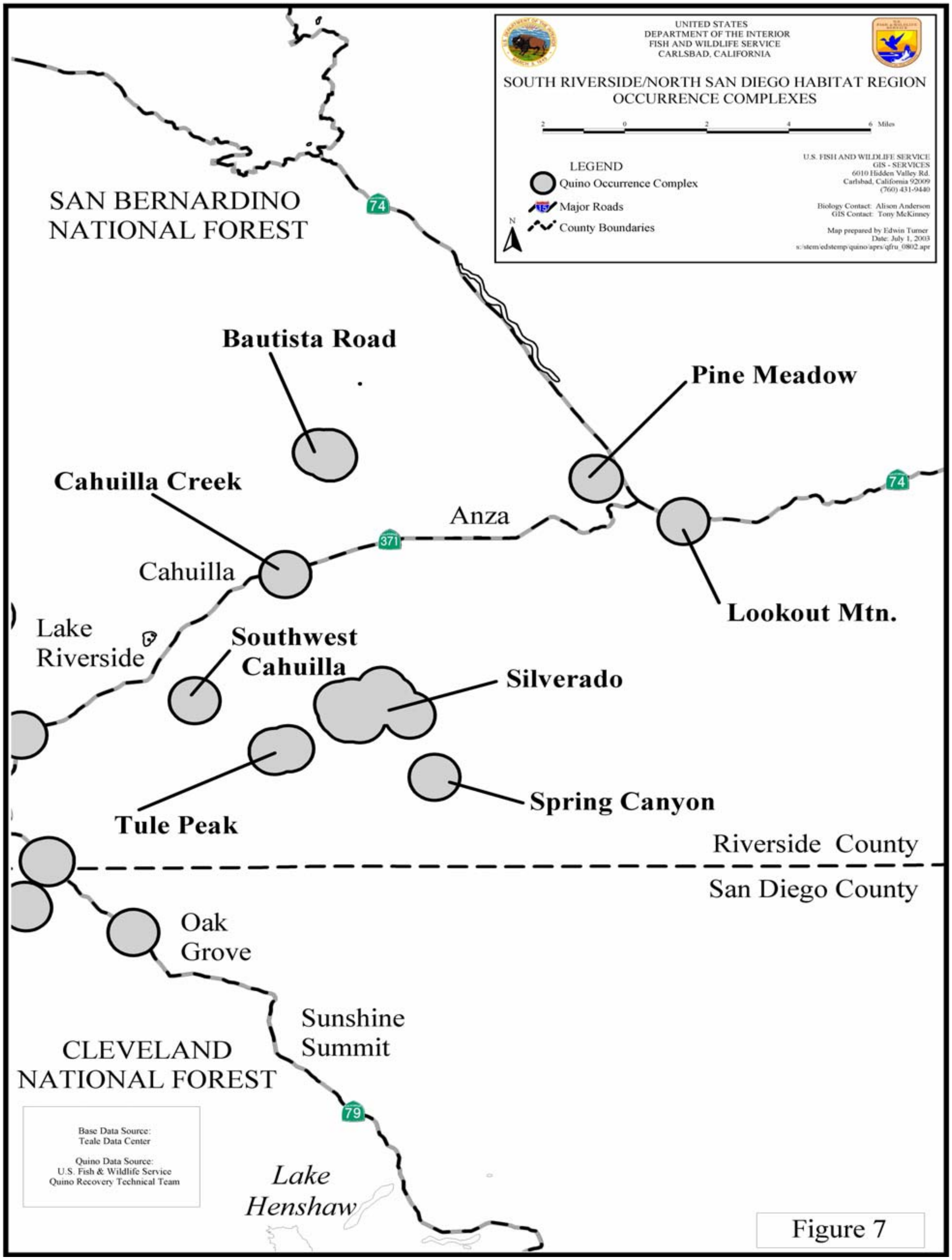
4. South Riverside/North San Diego County Habitat Region:

Southwest Cahuilla, Tule Peak (core), Silverado (core), Spring Canyon, Cahuilla Creek, Bautista Road, Pine Meadow, and Lookout Mountain Occurrence Complexes (Figure 7):

Recent Quino checkerspot butterfly observations are concentrated along the southern border of the Cahuilla Indian Reservation in the Tule Peak and Silverado Occurrence Complexes (Figure 7). Survey efforts in 2001 resulted in addition of the Tule Peak and the Bautista Road Occurrence Complexes (Figure 7). The Spring Canyon Occurrence Complex is located at the north end of Iron Springs Canyon (Figure 7). In 2002 and 2003, Quino checkerspot butterflies were observed just above 1,520 meters (5,000 feet) in elevation south of Garner Valley near the intersection of State Route 371 and State Route 74 (Pine Meadow and Lookout Mountain Occurrence Complexes; Figure 7). In 2003 a Quino checkerspot butterfly was observed in the parking lot of the Cahuilla Creek Casino that must have come from habitat in the surrounding area, resulting in identification of the Cahuilla Creek occurrence complex. Most Quino checkerspot butterfly records in this region occur between 1,220 and 1,520 meters (4,000 to 5,000 feet) in elevation.

Habitat Considerations:

This habitat region is generally located from 1,070 to 1,520 meters (3,500 to 5,000 feet) elevation between the southeast slope of Palomar Mountain and the desert's edge. Habitat primarily occurs on granitic soils in scrub and open areas within red shank chaparral. The eastern sites extend to above 1,220 meters (4,000 feet) in elevation, where known larval habitat is characterized by low ridges and broad washes lacking a clay soil component. Rainfall in the Silverado Occurrence Complex is higher than at any of the other known Quino checkerspot butterfly sites (G. Pratt unpubl. data), averaging approximately 50 centimeters (20 inches) per year (Oregon Climate Service 1995). *Antirrhinum coulterianum* and *Plantago patagonica* are the primary host plants found at the higher elevations in this region in Riverside County (G. Pratt 2001), but there are also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(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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SAN BERNARDINO
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Bautista Road
Pine Meadow
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Anza
371
Cahuilla
Lookout Mtn.
Lake
Riverside
Southwest
Cahuilla
Silverado
Spring Canyon
Tule Peak
Riverside County
San Diego County
Oak
Grove
Sunshine
Summit
CLEVELAND
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Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Lake
Henshaw

Figure 7

Cordylanthus rigidus records (Chuang and Heckard 1986). *Plantago patagonica*, *A. coulterianum* (Thompson 1988), and *C. rigidus*, are found in San Diego County habitats (A. Anderson pers. observ.).

Habitat patches appear to be well connected, except where lands have been developed north and west of the Cahuilla Tribal trust lands. Much of the Silverado Occurrence Complex is relatively well protected, but ongoing habitat destruction in the Southwest Cahuilla Occurrence Complex (and designated critical habitat) of least three sites estimated to be between 10-50 acres each in size was documented in 2003 (A. Anderson, pers. observ.). Most known occupied habitat areas are owned by the Bureau of Land Management, the San Bernardino National Forest, and Gregg Reeden (owner of the Silverado Ranch Pre-approved Mitigation Area), with portions of the occurrence complexes overlapping the Cahuilla Tribal trust lands. Surveyors expressed concern regarding habitat destruction by off-road vehicles in 2001 within the Tule Peak Habitat Complex (S. Reed, pers. comm. 2001). Landscape connectivity probably exists between the occurrence complexes in both San Diego and Riverside Counties, and between complexes in Riverside County through undeveloped lands east of the Cahuilla Tribal trust lands. Apparently suitable habitat has been observed in the southern portion of the region along Lost Valley Road, just north of State Route 79 near Warner Springs (Pratt 1999). The Lost Valley Road habitat appeared to be coastal sage scrub vegetation created by human clearing of chaparral along the roadside (A. Anderson, pers. observ.). The valley east of Lake Henshaw (San Jose Del Valle; currently leased rangeland), contains a large expanse of nonnative grassland with inclusions of scattered, diminutive *Eriogonum fasciculatum* shrubs and abundant *Plantago patagonica* host plants (A. Anderson pers. observ. 2001, K. Winter, pers. comm. 2001).

Experts who have done extensive work with the Quino checkerspot butterfly in San Diego County (G. Pratt and K. Osborne, pers. comm 2002) believe that the unique habitat in this habitat region may support the most stable (not just resilient) populations in the county. Apparent population stability may be attributable to a combination of high rainfall that mitigates drought conditions, the predominant use of a host plant (*Antirrhinum coulterianum*) that always persists long enough to support larvae to diapause when present, and other unique habitat characteristics. The habitat in this region is not typical for *A. coulterianum* either; throughout much of its range *A. coulterianum* grows in more closed-canopy vegetation (Thompson 1988), a situation that is not as conducive to larval development as the relatively open woody canopy found in occupied Quino checkerspot butterfly habitat near Anza.

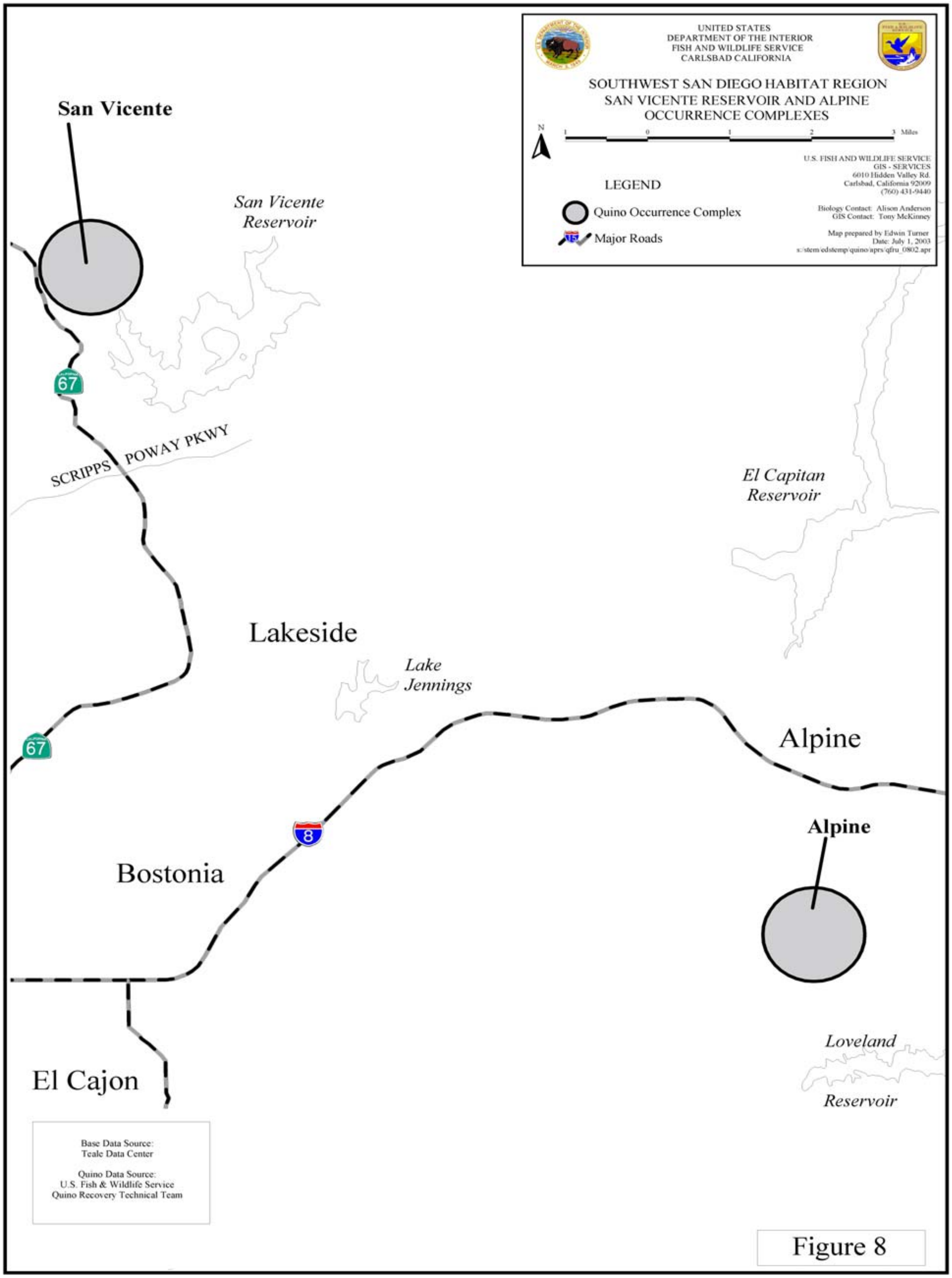
Because of the apparent stability, populations in this region may be important as a source of immigrants to the South Riverside habitat region. As demonstrated by the apparent timing of the 2003 Quino checkerspot butterfly flight seasons in Riverside County, in some years the higher elevation flight seasons can be relatively synchronized with those of lower elevations (U.S. Fish and Wildlife Service 2003; http://carlsbad.fws.gov/Rules/QuinoDocuments/Quino_htms /Flight_Info_2003.htm), making it possible for immigrants from higher elevations to colonize lower elevation sites. In fact, the drought season of 2002 appears to have almost extirpated the Lake Skinner population (only four butterflies were observed where they are normally abundant), indicating that following prolonged drought, recolonization of lower elevation sites by individuals from higher elevation populations may be necessary.

5. Southwest San Diego Habitat Region

Northern Occurrences; San Vicente Reservoir and Alpine Occurrence Complexes (Figure 8):

During the 2001 flight season, two Quino checkerspot butterflies were reported from the hills north of San Vicente Reservoir (Sproul and Faulkner 2001). Documentation included several distinct photographs. There is also evidence of prior occupancy in the hills north of San Vicente Reservoir in 1992, and more evidence of recent occupancy in Sycamore Canyon Open Space Preserve west of State Route 67 (Appendix V). During the 2003 flight season two Quino checkerspot butterflies were also reported just south of currently developed land in the vicinity of the community of Alpine (Lee 2003).

Southern Occurrences; West Otay Mesa, Otay Valley (core), West Otay Mountain (core), Otay Lakes/Rancho Jamul (core), Proctor Valley, Jamul, Hidden Valley, Rancho San Diego, Los Montañas, Honey Springs, Dulzura, Marron Valley (core), Barrett Junction, and Tecate Occurrence Complexes (Figure 9):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LEGEND
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Map prepared by Edwin Turner
Date: July 1, 2003
San Vicente
San Vicente Reservoir
67
SCRIPPS POWAY PKWY
El Capitan Reservoir
Lakeside
Lake Jennings
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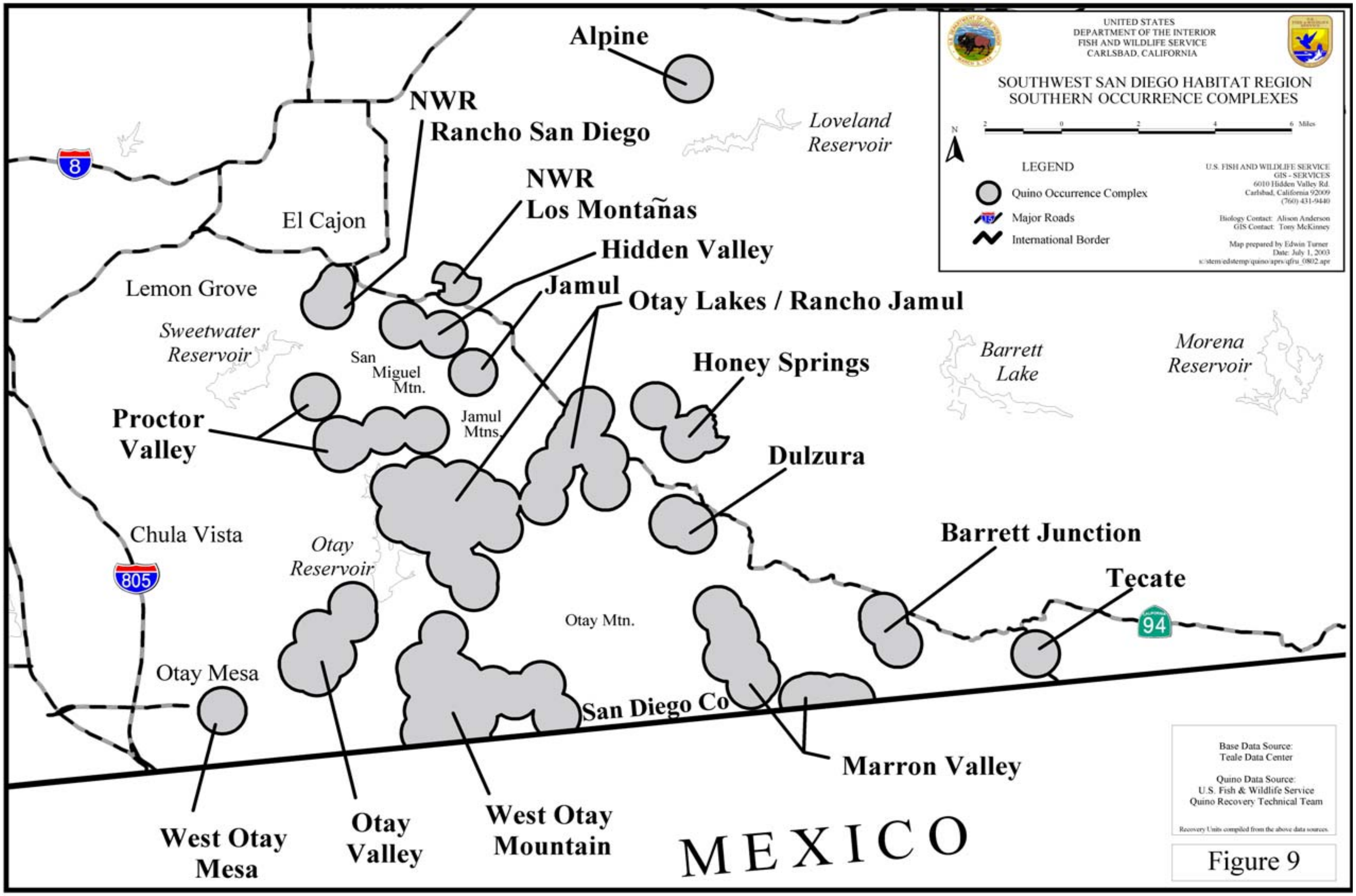
U.S. Fish & Wildlife Service
Quino Recovery Technical Team

Figure 8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GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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Alpine
NWR
Rancho San Diego
NWR
Los Montañas
Hidden Valley
Jamul
Otay Lakes / Rancho Jamul
Honey Springs
Dulzura
Barrett Junction
Tecate
Proctor
Valley
Loveland
Reservoir
El Cajon
Lemon Grove
Sweetwater
Reservoir
San
Miguel
Mtn.
Jamul
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Barrett
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Morena
Reservoir
Chula Vista
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U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

Figure 9

Recent Quino checkerspot butterfly observations in southwestern San Diego County are concentrated in lower elevation areas surrounding east Otay Valley, Otay Mountain, the Jamul Mountains, and San Miguel Mountain. The Otay Lakes area historically supported large, high density local populations (White and Levin 1980, Murphy and White 1984). Historic population distributions extended across Otay Mesa, with high densities reported from the vicinity of Brown Field (Murphy and White 1984). A Quino checkerspot butterfly was observed in 2001 in a vernal pool habitat restoration project on the mesa top between Dennery and Spring Canyons, resulting in identification of the West Otay Mesa Occurrence Complex. Other 2001 observations resulted in delineating a western extension of the Otay Lakes/Rancho Jamul Occurrence Complex, and identification of the Los Montañas, Hidden Valley, Jamul, and Dulzura Occurrence Complexes. The Rancho San Diego and Los Montañas Occurrence Complexes are on the Otay/Sweetwater Unit of the San Diego National Wildlife Refuge. Recent Quino checkerspot butterfly observations east of Otay Mountain are concentrated on the eastern slope of Otay Mountain and ridgelines along the international border in the vicinity of Marron Valley (Figure 9). Two other recent records of the butterfly are located east of Otay Mountain, one near Barrett Junction, and another near the town of Tecate (Figure 9). Observations reported in 2003 resulted in identification of the Honey Springs Occurrence Complex (Figure 9). Occupancy extends across the international border south of Otay Mountain (D. Murphy and M. Dodero, pers. comm. 2001). It is possible that the West Otay Mountain and Marron Valley Occurrence Complexes belong to a metapopulation dependent on local mainland or "source" populations in Mexico (C. Parmesan, pers. comm. 2001).

Habitat Considerations:

This habitat region is generally located in southwestern San Diego County, and includes recently discovered occurrences in the vicinity of Alpine and San Vicente Reservoir (Figure 8), as well as several southern occurrence complexes in the vicinity of Otay Mountain (Figure 9). This region contains the only vernal pool/mima mound mesa habitat characteristic of historic Quino checkerspot butterfly population centers that remains within the current distribution of the butterfly. The Otay Mesa habitat containing the vernal pools also is the only known occupied habitat with a marine climate influence. Marine climate influence was prevalent throughout most of the species' historic range and is thought to be beneficial to population resilience because it provides climatic stability and higher average humidity, minimizing host plant susceptibility to drought. Soils contain both granitic and clay components. *Plantago erecta* is the most abundant host plant found in this area, but *Castilleja exserta* is also present within most of the occurrence complexes (A. Anderson, pers. observ.), and *Antirrhinum coulterianum* has been collected just north of State Route 94 (Thompson 1988).

Landscape connectivity remains relatively intact in the vicinity of the San Vicente Reservoir Occurrence Complex, except where it is compromised by ongoing development associated with the City of Poway and the town of Ramona. Landscape connectivity with potentially occupied habitat to the west is slightly compromised by increasing traffic load on State Route 67. Large areas of habitat in the vicinity have been conserved, including the San Vicente Occurrence Complex, the City of Poway's Iron Mountain Open Space Preserve to the north, and the County of San Diego's Sycamore Canyon Open Space Preserve to the west. Ecological connectivity (lands in a natural state), and possibly landscape connectivity (intervening habitat patches) extend west and south into Marine Corps Air Station Miramar and the City of San Diego's Mission Trails Regional Park. It is also probable that landscape connectivity extends east of the occurrence complex (G. Pratt, pers. comm. 2001), providing the only possibility for connectivity with the Alpine occurrence complex and southern occurrence complexes.

Landscape connectivity between the southern occurrence complexes appears to be mostly intact. In addition, some degree of landscape connectivity apparently exists south of Otay Mountain in Baja California, Mexico, between the west Otay Mountain and Marron Valley Occurrence Complexes. A combination of the regional distribution of occurrence complexes (Figure 9), historic records and accounts (Figure 2; Murphy and White 1984), and geographic features suggests that habitat in the Otay Lakes area is a regional keystone with regards to Quino checkerspot butterfly landscape connectivity. If hilly or mountainous terrain reduce the ability of *Euphydryas editha* to locate and colonize habitat patches (Harrison 1989) and support less suitable habitat than lower elevation areas; and if development (including agriculture) also compromises landscape connectivity, then the Otay Lakes/Rancho Jamul Occurrence Complex is not only a documented historic population center (Murphy and White 1984), but a confluence of landscape connectivity for all populations in the Southwest Habitat Region (Figure 9). Landscape connectivity is severed by development at the western periphery of these occurrence complexes (no habitat to connect to, ongoing development), and is compromised by ongoing development and agriculture in the vicinity of the town of Jamul. Landscape connectivity appears to be constrained between some occurrence complexes by intervening hills and mountains, primarily Otay Mountain, San Miguel Mountain, and the Jamul Mountains. Landscape connectivity to the Alpine Occurrence Complex appears to be least constrained by vegetation and other less suitable habitat characteristics in the area northeast of Honey Springs and Rancho Jamul, but may be intact directly north of Rancho Jamul.

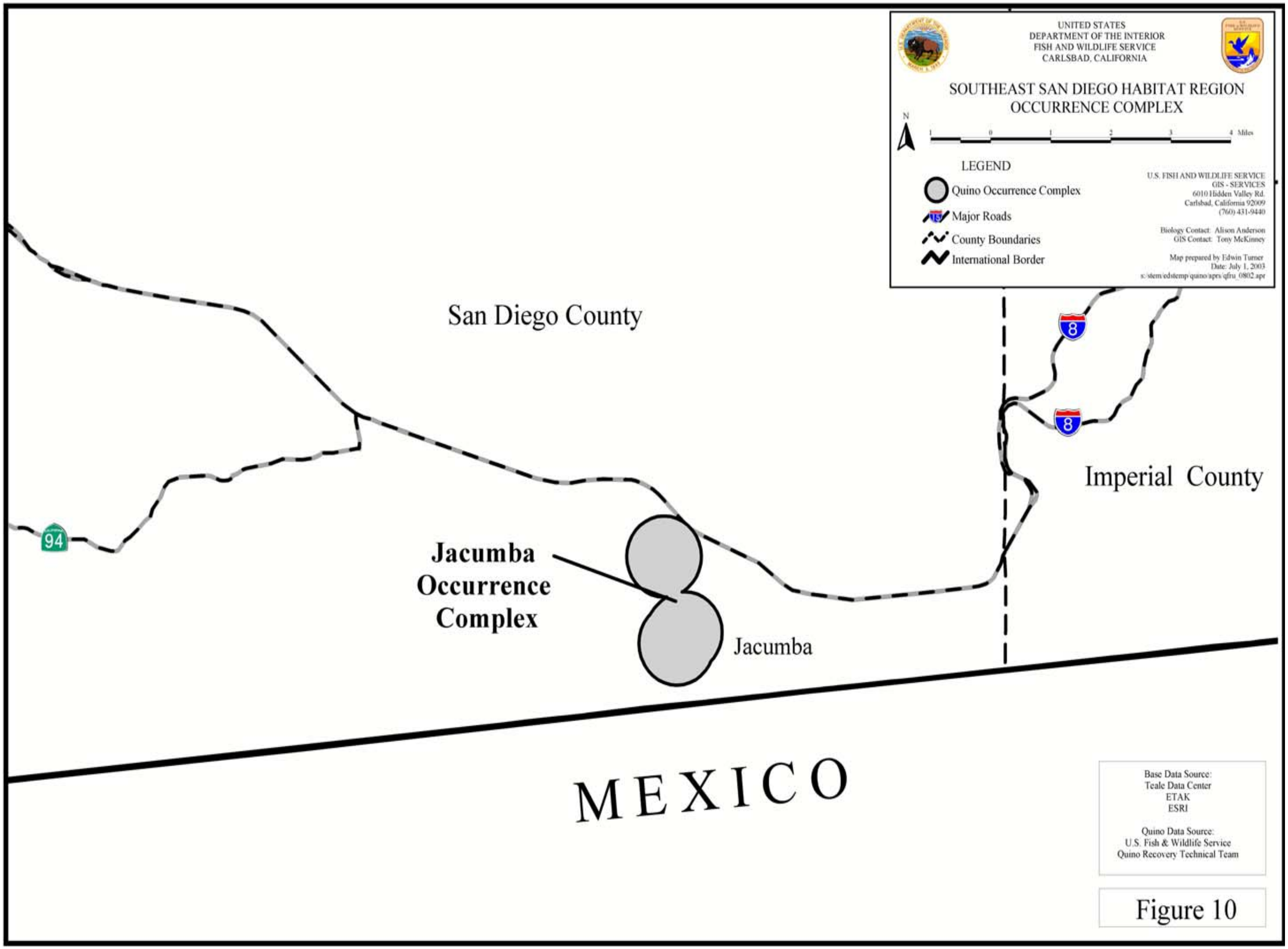
6. Southeast San Diego Habitat Region

Jacumba Occurrence Complex (Figure 10):

Recent Quino checkerspot butterfly observations are concentrated northwest of the town of Jacumba (Figure 10), in the vicinity of Jacumba Peak, and within the Anza Borrego Desert State Park boundary south of Interstate 8. The Jacumba Occurrence Complex and occupied habitat in El Condor in Baja California, Mexico, are about 6 kilometers (4 miles) apart. One historic Quino checkerspot butterfly record from 1947 occurs north of Interstate 8 within the Bureau of Land Management Table Mountain National Cooperative Land and Wildlife Management Area.

Habitat Considerations:

This habitat region is located in the high-desert transition area between the Anza Borrego Desert and the international border. The habitats in this region are composed primarily, but not exclusively, of dark brown clay lenses and adjoining sandy, rockier areas on gentle north-facing slopes. Occupied habitat is found in open juniper woodlands. Barren soils in more exposed areas (*i.e.,* without woodland vegetation) do not support host plants. The vegetation in this area is a diverse mixture of desert and coastal slope communities. *Plantago erecta* and *P. patagonica* are the primary host plants found in the area, and both occur together in the occupied habitat below Jacumba Peak (A. Anderson pers.


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD, CALIFORNIA
SOUTHEAST SAN DIEGO HABITAT REGION
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Quino Occurrence Complex
Major Roads
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U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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U.S. Fish & Wildlife Service
Quino Recovery Technical Team

Figure 10

observ.). Habitat in the Jacumba area has not been heavily invaded by nonnative plants, and these resident Quino checkerspot butterfly populations may be the only ones that will not require extensive management to reduce or prevent degradation due to nonnative plant invasion (G. Pratt, pers. comm. 1999). Habitat and landscape connectivity in the Jacumba area are relatively intact, with limited fragmentation occurring near Jacumba Peak (A. Anderson, pers. observ. 2001). Landscape connectivity between apparently suitable habitat in the Table Mountain area and the Jacumba Occurrence Complex has been compromised by Interstate 8, and appears to be constrained by intervening hills and ridges composed primarily of boulders and large rock outcrops (A. Anderson, pers. observ. 2001).

Although degraded by grazing in some areas, apparently suitable habitat also exists northwest of Jacumba in the vicinity of McCain Valley (M. Dodero, pers. comm. 2000). Connectivity likely exists between the Jacumba Occurrence Complex, the Table Mountain area, and occupied habitat in El Condor in Baja California, Mexico.

<u>7. Baja California, Mexico</u>:

All populations of the Quino checkerspot butterfly near the ocean in Baja California, Mexico, appear to have been extirpated by urban development. Many sites farther inland, however, appear to support excellent habitat and dense populations, including a semi-pristine site discovered in 2001, south of Otay Mountain (M. Dodero, D. Murphy, pers. comm. 2001). Unlike most California populations, which probably occur in marginal habitat on the periphery of historic metapopulation centers, most of the extant Baja California, Mexico, populations occur in apparently high-quality habitat.

The newly discovered population area south of Otay Mountain appears to be connected to both the Marron Valley and West Otay Mountain Occurrence Complexes, although more research is required to determine the extent of connectivity. There is one population south of El Testerazo along Highway 3. A population also exists at Mesa Redonda (also known as Table Mountain) just east of the city of Rosarita. Another population in Valle de Trinidad was known as “Los Aguajitos” in museum records, but the area is now called “Los Positos.” The three southernmost Quino checkerspot butterfly population sites south of the

West Otay Mountain and Marron Occurrence Complexes are distant from each other and are probably independent populations. A population also exists south of the Jacumba area, about 6 kilometers (4 miles) south of the town of El Condor, and may be connected to the Jacumba Occurrence Complex.

E. Reasons for Decline and Current Threats

The Quino checkerspot butterfly is threatened primarily by urban and agricultural development, invasion by nonnative species, off-road vehicle use, grazing, and fire management practices (U.S. Fish and Wildlife Service 1997a). Other factors contributing to the species' population decline likely have been, and will continue to be, enhanced nitrogen deposition (Allen *et al.* 1998), elevated atmospheric carbon dioxide concentrations (Coviella and Trumble 1998), and climate change (Parmesan 1996, Field *et al.* 1999, Parmesan in press). Nonetheless, urban development poses the greatest threat and exacerbates other threats. As a result, careful planning that ensures maintenance of existing Quino checkerspot butterfly metapopulations will be the key to long-term conservation of the species. Any activity resulting in habitat fragmentation or removal of host or nectar plants from habitat reduces habitat quality and increases the probability of extinction of the Quino checkerspot butterfly.

When the Quino checkerspot butterfly was listed under the Endangered Species Act, predation and collecting were identified as possible threats (U.S. Fish and Wildlife Service 1997a). Stamp (1984) and White (1986) examined parasitism and predation of the genus *Euphydryas*, although it is not clear whether these mortality factors pose a significant threat to the species. Predation by Argentine ants (*Iridomyrmex humilis*) has been observed in Quino checkerspot butterfly laboratory colonies (G. Pratt, pers. comm.), and predation by imported Brazilian fire ants (*Solenopsis invicta*) is likely if they were to co-occur with the butterfly (Porter and Savignano 1990). Brazilian fire ants were discovered in 1998 in the vicinity of historic Quino checkerspot butterfly habitat in Orange County, and have subsequently been found in San Diego, Riverside, and Los Angeles Counties (California Department of Food and Agriculture 1999). Over-collection by hobbyists and dealers is also considered a threat (U.S. Fish and Wildlife Service 1997a, E. Hein *in litt.* 2003), although the current impact of this threat is unknown.

Unfortunately, our assessment in the draft recovery plan that "the species continues to decline throughout its range" (U.S. Fish and Wildlife Service 2001b) was not negated by the discovery of new occupied sites in Riverside and San Diego Counties during the 2001 flight season. Reports of habitat destruction and degradation at newly discovered Quino checkerspot butterfly sites frequently accompanied reports, and the same was true for many monitored reference sites. Threats most commonly reported were off-road vehicle damage, exotic plant invasions, and trash dumping (K. Osborne, G. Pratt, and S. Reed, E. Stanton, pers. comm.; A. Anderson, pers. observ.). These factors combine to result in type-conversion from native forbland and scrub habitat to chronically disturbed "dumps" dominated by nonnative plants such as *Bromus diandrus* (ripgut grass) and *B. tectorum* (cheat grass) (A. Anderson pers. observ.).

1. Loss and Fragmentation of Habitat and Landscape Connectivity

More than 90 percent of the Quino checkerspot butterfly's historic range has been lost due to habitat degradation or destruction (D. Murphy, pers. comm.). Most of the species' preferred habitat, mesa tops in particular, has been destroyed or is currently threatened by residential, urban, and industrial development and associated indirect impacts on adjacent undeveloped areas.

The probability that suitable habitat patches temporarily not supporting larval development will be recolonized is decreased as metapopulation distributions are reduced and habitat becomes more fragmented. Low population densities reduce dispersal rates and generally make metapopulations more vulnerable to extirpation. Small, isolated, or poorly connected metapopulations are subject to higher rates of genetic drift and inbreeding depression, resulting in reduced genetic variability. Inbreeding depression, or lowered fitness resulting from breeding among closely related individuals, has been documented in the Glanville fritillary (*Melitaea cinxia*), a relative of the Quino checkerspot butterfly (Saccheri *et al.* 1998, Niemen *et al.* in press). Reduced genetic diversity usually decreases the ability of a species to adapt to changing environmental conditions. A large, well-connected metapopulation allows the genetic exchange among habitat patches needed to maintain a genetically diverse pool of individuals.

Research has demonstrated that intact landscape and habitat connectivity promotes persistence of other subspecies of *Euphydryas editha* across a landscape (Murphy and White 1984, Harrison *et al.* 1988, Harrison 1989, Singer and Thomas 1996). Although a year of extremely high rainfall appears to have prompted active long-distance dispersal of Quino checkerspot butterflies in the 1970's (Murphy and White 1984), the apparent rarity of this event, current low population numbers, and reduced population distributions decrease the probability that such natural, long-distance dispersal could reestablish occupancy in isolated habitat patches. Efforts need to be made to reestablish and maintain habitat and landscape connectivity within and between the recovery units.

2. Invasion by Nonnative Plants

Nonnative annual grasses and forbs have invaded Quino checkerspot butterfly habitat and dominate many areas throughout the range of the species, displacing native shrubs and forbs (Freudenberger *et al.* 1987, Minnich and Dezzani 1998, Stylinski and Allen 1999). Nonnative plants invade more rapidly following fire or other disturbance and can displace *Plantago erecta*, which appears to be a poor competitor against nonnative grasses. In addition to displacing larval host plants, nonnative annuals have been replacing nectar plants, including dominant shrubs of coastal sage scrub, throughout the historic range of the butterfly (Freudenberger *et al.* 1984, Minnich and Dezzani 1998, Stylinski and Allen 1999).

The few existing experimental studies on *Plantago erecta* have been carried out in northern California on serpentine grassland. After early fall rains, *P. erecta* germinated later than a nonnative grass, *Bromus mollis* [=*B. hordeaceus*] (soft chess) (Gulmon 1992). Similarly, *P. erecta* decreased during years of high rainfall, correlated with high productivity of *B. mollis* (Hobbs and Mooney 1991). *Bromus mollis* was more competitive than *P. erecta* in greenhouse experiments (Koide *et al.* 1987), and nitrogen fertilization decreased the size and density of *P. erecta* (Koide *et al.* 1988). These studies indicate that weed competition will reduce the occurrence of *P. erecta* in exotic annual grassland. The most abundant nonnative plants include species of *Bromus* (brome grass), *Avena* (oat grass), *Hordeum* (foxtail barley), *Brassica* (mustard), and *Erodium* (red-stem filaree).

Conversion from native vegetation to nonnative annual grassland will be the greatest threat to Quino checkerspot butterfly reserves, based on observations of large-scale invasions throughout the range (Freudenberger *et al.* 1984, Minnich and Dezzani 1998, Stylinski and Allen 1999). The increased dominance of nonnative species may reduce the abundance of Quino checkerspot butterfly food sources (Koide *et al.* 1987), and habitat fragmentation exacerbates vegetation type conversion because ground disturbance and edge effects in fragments with large edge-to-area ratios experience higher rates of invasion. Corridors of human activity through unfragmented natural areas such as unpaved roads, trails, and pipelines are also conduits of nonnative seed dispersal (Zink *et al.* 1995). Other causes of vegetation type conversion include fire, grazing, off-road vehicle activity, and increased nitrogen deposition (Allen *et al.* 2000).

Once invasion by nonnatives has occurred, natural succession likely will not allow for the complete recovery of the site to a pre-disturbance state. For example, after surveying 25 coastal sage scrub and chaparral sites disturbed up to 70 years ago in San Diego County, Stylinski and Allen (1999) concluded that all the original plant communities were significantly altered by nonnative plant invasion. These sites were primarily disturbed by mechanical means such as agriculture, landfills, and grading, but sites that have been subject to disturbances that remove vegetation without disrupting the soil, such as frequent fire, also contain persistent stands of nonnative vegetation (Freudenberger *et al.* 1984, Minnich and Dezzani 1998). These kinds of studies indicate that active restoration will be required to control nonnative annuals and reestablish native vegetation. Even disturbance events that do not directly threaten Quino checkerspot butterfly populations do so indirectly by exacerbating nonnative invasion, as explained below. Methods for restoration and controlling invasive species are described in Appendix II.

3. Off-road Vehicle Activity

Quino checkerspot butterfly populations are threatened in many areas by frequent off-road vehicle use. The level of off-road vehicle damage and its effects on Quino checkerspot butterfly populations are increasing as the amount of available undeveloped land decreases. Off-road vehicle use compacts soil, destroys host plants, increases erosion and fire frequency, creates trails that are conduits of nonnative plant invasion (Frenkel 1970), and causes egg and larval mortality. Although off-road vehicles can destroy suitable habitat and damage butterfly populations, they can also temporarily create habitat if the traffic reduces canopy cover in unoccupied areas (Osborne and Redak 2000; G. Pratt, pers. comm.). However, continued disturbance of subsequently occupied habitat created by off-road vehicles is likely to create a mortality sink because the occurrence of Quino checkerspot butterfly larvae and egg distribution is correlated with bare or sparsely vegetated areas (Osborne and Redak 2000, Pratt 2000) where off-road vehicle and other traffic is most likely to occur. Eggs, which take 2 weeks to develop, and prediapause larvae, which can take an additional 2 weeks, are susceptible to being crushed by off-road vehicle traffic. Prediapause larvae cannot travel great distances and are restricted to a small area near the plant where their mother deposited her eggs. Since postdiapause larvae also tend to bask on open soils and pupate in this type of habitat (Osborne and Redak 2000), they are also susceptible to being crushed.

Detrimental effects of off-road vehicle use have been observed at the Wilson Valley site in Riverside County, where motorcycles destroyed plants with egg and larval clusters. At Oak Mountain, one clay lens habitat where female Quino checkerspot butterflies were observed one spring was destroyed by off-road vehicles (as evidenced by many tire-tracks), and no *Plantago* could be found there the following spring (G. Pratt, pers. comm.). Off-road vehicle activity must be managed within the recovery units.

4. Grazing

The impacts of grazing on Quino checkerspot butterfly habitat vary depending on the species grazing and the timing, intensity, and duration of grazing. Generally, impacts include larval host plant destruction, soil compaction, cryptogamic crust degradation, and egg and larval trampling (M. Dodero, pers. comm.). Grazing by sheep and goats is more intensive than grazing by cattle, and apparently precludes Quino checkerspot butterfly survival.

Consumption of nonnative plants by domestic animals has been used as a tool to prevent further deterioration of already degraded bay checkerspot butterfly habitat restricted to serpentine soils. In the short term, cattle may reduce nonnative grass invasion rates in already degraded habitat through preferential grazing and enhanced nitrogen exportation (Weiss 1999). However, cryptogamic crusts, which inhibit invasion by nonnative plants, are also extremely vulnerable to trampling. Cattle have been observed to cause disturbance to cryptogamic crusts in Quino checkerspot butterfly habitat and increase initial rates of invasion by nonnative plants (M. Dodero, pers. comm.). Livestock have been found to contribute to nonnative plant invasion in the arid western United States by: a) transporting seeds into uninfested sites; b) preferentially grazing native plant species; c) creating bare, disturbed patches of soil and destroying crusts; d) increasing soil nitrogen concentration (if they are not managed to enhance exportation); e) reducing soil mycorrhizae; and f) accelerating soil erosion (Belsky and Gelbard 2000). Observations of coastal sage scrub in the Western Riverside County Multiple Species Reserve indicate native forbs were readily consumed if grazing occurred at the time of year when they were abundant and flowering (E. Allen, pers. comm.). Although studies are underway, it is doubtful that even carefully controlled grazing can effectively reduce nonnative plant invasion in the variety of habitats that harbor the Quino checkerspot butterfly as it has for bay checkerspot butterfly populations (Weiss 1999). Commercial grazing should be phased out and replaced by other, less destructive, nonnative plant control methods. Intact cryptogamic crusts appear to exclude nonnative plant invasion better than cattle grazing (M. Dodero, pers. comm.). Experiments that control timing and intensity of grazing to control weeds in disturbed habitat outside of habitat patches are still warranted.

5. Fire

Increased fire frequency is a cause of native California plant community decline, and therefore a threat to Quino checkerspot butterfly survival. Frequent fire is caused by increased human populations (increased ignition sources), and by increased habitat fragmentation and transportation corridors that allow highly flammable nonnative plants to penetrate undeveloped lands. Studies have shown that short fire intervals of 5 years or less cause conversion of shrubland to grassland, enhancing nonnative grass invasion (Zedler *et al.* 1983, Malanson 1985, Calloway and Davis 1993). The typical fire return interval in coastal sage scrub is approximately 30 years (Keeley and Keeley 1984, Westman and O'Leary 1986). Under shorter fire intervals, shrubs, unlike annuals, cannot grow to maturity and reproduce. Urban parks in western Riverside County (such as Box Springs Mountain and Mount Rubidoux, which were dominated by coastal sage scrub 20 years ago) are now largely annual grasslands because of fires that burned at 2 or 3 year intervals (Minnich 1988). Thus, frequent fire results in the loss of shrubland in urban reserves where ignitions are frequent. Nonnative annual grasses contribute to increased fire frequency by forming continuous fuel more flammable than native shrublands.

The overall impact of fire on Quino checkerspot butterfly habitat depends on the intensity, frequency, and season of occurrence of fire and the size of the invasive nonnative seed bank (Mattoni *et al.* 1997). Given the restricted and fragmented Quino checkerspot butterfly distributions, and low population densities, even historic natural fire frequency could permanently extirpate local populations in remaining isolated habitat patches that have little chance of natural recolonization. Although fire may have historically played a positive role in metapopulation dynamics by creating openings for new habitat patches, such is not the case where weed invasion follows fire. Also, dense populations of *Plantago erecta* have not been observed following fire, indicating the species either lacks a dormant seed bank or requires a light burn for seed survival (J. Keeley, pers. comm.). Fires are particularly common near the international border and southern Quino checkerspot butterfly populations. Frequent wildfires can be reduced by controlling exotic grasses, which are the major ignition fuel source. In addition, controlled burns over small areas should be implemented to avoid landscape-scale wildfires. Some controlled burn experiments should be conducted in Quino checkerspot butterfly habitat, to test the effects of such burns.

6. Enhanced Soil Nitrogen

Another factor that influences nonnative plant invasion is soil fertility, as invasive species are often better competitors for soil nutrients than are native plant species (Allen *et al.* 1998). Soils in urbanized and agricultural regions are being fertilized by excess nitrogen generated by human activities. Burning of fossil fuels, production of fertilizer, and cultivation of nitrogen-fixing crops now add as much nitrogen to global terrestrial ecosystems as do all natural processes combined (Vitousek *et al.* 1997).

Nitrogen deposition has been found to cause conversions from high-diversity shrub-grasslands to low-diversity grasslands in other regions of the world, notably the Netherlands where as much as 90 kilograms of nitrogen is deposited per hectare per year (80 pounds per acre per year) (Bobbink and Willems 1987). Southern California currently experiences up to 45 kilograms per hectare per year (40 pounds per acre per year) of nitrogen deposition, compared to the background level of about 1 kilogram per hectare per year (0.9 pounds per acre per year) (Bytnerowicz *et al.* 1987, Fenn *et al.* 1996). Most nitrogen arrives during the dry season as nitrate dryfall (particulate and ion deposition to surfaces) produced by internal combustion engines. Soils in the most polluted regions near Riverside, California, have more than 80 parts per million (weight) extractable nitrogen, a value more than four times that detected in natural, unpolluted soils (Allen *et al.* 1998, Padgett *et al.* 1999).

Nitrogen fertilization experiments near Lake Skinner (where air pollution is relatively low) demonstrated that after 4 years the cover and biomass of nonnative grasses increased and native shrub canopy decreased (Allen *et al.* 2000). These experiments suggest that the rate of loss and degradation of Quino checkerspot butterfly habitat will continue, and may increase, in and near nitrogen polluted lands. Nitrogen deposition in coastal areas of southern California is less severe than inland areas because prevailing winds move pollution inland (Padgett *et al.* 1999). High emissions from nitrogen sources in Mexico could threaten adjacent Quino checkerspot butterfly populations in California. Restoration of N-eutrophied soils will depend upon future local reductions of nitrogen emissions. In the meantime, exotic grass productivity will continue to be high, and more extensive weed control will be necessary in most Quino checkerspot butterfly habitat.

7. Increasing Atmospheric Carbon Dioxide Concentration

Increasing atmospheric carbon dioxide gas concentration has direct effects upon the vegetation and indirect effects on associated insects. Atmospheric concentrations of carbon dioxide have risen from a stable 270 parts per million volume prior to the 1900's, to 364 parts per million volume today, and continue to rise at a rate of 0.4 percent per year (IPCC 1996). Unlike atmospheric nitrate or ammonium that deposit along gradients from the source of emissions, carbon dioxide is globally mixed and thus has global impacts (IPCC 1996). Carbon dioxide has been shown to increase plant growth and photosynthesis rates, increase leaf tissue (foliar) carbon to nitrogen ratio (C:N), and increase production of carbon-based defense compounds (IPCC 1996, Coviella and

Trumble 1999). Increased plant photosynthesis and biomass in chaparral (Oechel *et al.* 1995) and scrub communities will likely contribute to increased canopy closure and reduction of habitat favored by the Quino checkerspot butterfly. These chemical changes in plant tissue have been found to affect food quality for herbivores, and often resulted in reduced performance of leaf-eating insects (reviews by Lindroth 1995, Bezemer and Jones 1998, Coviella and Trumble 1999, and Whittaker 1999).

Responses to carbon dioxide increases by larvae of the buckeye butterfly (*Junonia coenia*, a co-occurring relative of the Quino checkerspot butterfly), feeding on *Plantago lanceolata* (English plantain, a co-occurring close relative of *P. erecta*), are particularly relevant. When the atmospheric carbon dioxide concentration was approximately doubled, effects included a 36 percent increase in larval mortality, increased development time, and decreased biomass (Fajer 1989; Fajer *et al.* 1989, 1991). Buckeye butterfly research results are generally consistent with those of other studies encompassing taxonomically diverse representatives of the order Lepidoptera, suggesting similarly negative effects may be experienced by Quino checkerspot butterflies. An extended development time in early instar prediapause larvae would increase the probability of mortality due to early host plant decline and predation (see section I.C.3, Climate Effects, and section I.E.8, Climate Change). Research into the effects of elevated carbon dioxide on the Quino checkerspot butterfly, in both the field and the laboratory, should be conducted. When the direct effects of elevated carbon dioxide on the Quino checkerspot butterfly are better understood, it will be possible to recommend appropriate adaptive management tools.

8. Climate Change

Evidence of local climate change and a corresponding change in the Quino checkerspot butterfly's range-wide distribution supports the conclusion that climate change is a substantial threat to the species' survival in the foreseeable future. A trend toward warming in the last century has been linked to elevated greenhouse gases globally (Karl *et al.* 1996, IPCC 1996, Easterling *et al.* 1997), and locally in southern California (Field *et al.* 1999, Environmental Protection Agency 2001). The National Academy of Sciences (2001) recently assessed the status of research on climate change within the scientific community, affirming the validity of climate change findings and warning of severe impacts to natural ecosystems if ignored. Regional warming is suspected to be contributing to the extirpation of populations of *Euphydryas editha*, with disproportional losses among Quino checkerspot butterfly populations (Parmesan 1996, Parmesan, in press). The suspicion is that drier winter-spring cycles have reduced host plant density and altered the critical timing of host plant availability.

Although concerns about a drier climate damaging butterfly populations may seem to contradict predictions of increased El Niño frequency, this is not the case. The El Niño phenomenon is a marine current change, often, but not always, accompanied by increased precipitation. Despite increased El Niño event frequency and intensity (IPCC 1996), southern California is one of the few regions apparently receiving less overall precipitation (Karl *et al.* 1996). Even if more frequent El Niño events eventually result in increased total annual precipitation, warmer temperatures and increased evaporation rates could still cause habitats to be drier during the crucial late spring months, and host plants would decline more quickly than in the past (Field *et al.* 1999).

Using historical records and recent field surveys, Parmesan (1996) compared the distribution of *Euphydryas editha* in the early part of the 20th century to their distribution from 1994 to 1996. She found the southernmost populations, including the Quino checkerspot butterflies, had the greatest number of disappearances (80 percent of previously known populations) while northernmost populations had the lowest (fewer than 20 percent). This skewed detection pattern indicates contraction of the southern boundary of the species' distribution by almost 160 kilometers (100 miles), and a shifting of the mean location of *Euphydryas editha* populations northward by 92 kilometers (57 miles); closely matching recent shifts in mean yearly temperature (Parmesan 1996). An explanation for the apparent pattern is that climate trends contributed to increased prediapause larval death due to early host plant aging at the southern range edge. Parmesan's (1996) observations suggest that the Quino checkerspot butterfly may be at risk from the effects of ongoing regional warming and drying. The likelihood of range shifts occurring in North American butterfly species is also supported by the recent documentation of range-shifts by one-third of European butterfly species with a much more extensive monitoring history (Parmesan *et al.* 1999). These European species are similar to the Quino checkerspot butterfly in that they are generally nonmigratory, fairly sedentary, host plant specialists.

In light of the recent warming and drying trends, prudent design of reserves and other managed habitats should include landscape connectivity to other habitat areas and ecological connectivity with undeveloped lands in order to accommodate range shifts northward and upward in elevation.

F. Current and Evolving Conservation Measures

Since listing of the Quino checkerspot butterfly in 1997, several conservation efforts have been undertaken by various Federal, State, and local agencies and private organizations. This section briefly describes statutory protections and a variety of on-the-ground conservation efforts.

Section 9 of the Endangered Species Act prohibits any person subject to the jurisdiction of the United States from taking (*i.e.,* harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting) listed wildlife species. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. Regulations implementing the Endangered Species Act (50 CFR 17.3) define "harm" to include significant habitat modification or degradation that results in the killing or injury of wildlife, and intentional or negligent "harassment" as acts that significantly impair essential behavioral patterns (*i.e.,* breeding, feeding).

Section l0(a)(1)(A) of the Endangered Species Act and related regulations provide for permits that may be granted to authorize activities otherwise prohibited under section 9, for scientific purposes or to enhance the propagation or survival of a listed species.

Section 10(a)(1)(B) of the Endangered Species Act allows permits to be issued for take that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity". Section 10(a)(2)(B) states that permitted take must “not appreciably reduce the likelihood of the survival and recovery of the species in the wild”. Under these sections, an applicant must prepare a habitat conservation plan that specifies the impacts of the proposed project and the steps the applicant will take to minimize and mitigate the impacts of the project. The Quino checkerspot butterfly is currently addressed in three approved habitat conservation plans: the Orange County Central-Coastal Natural Community Conservation Plan (Central-Coastal NCCP) (described below), the Lake Mathews Habitat Conservation and Impact Mitigation Program, and the Assessment District 161 Subregional Habitat Conservation Plan, Western Riverside County. The Riverside County Assessment District 161 Subregional Habitat Conservation Plan includes a general program integrating Quino checkerspot butterfly habitat protection, habitat restoration research, educational outreach, and captive propagation (U.S. Fish and Wildlife Service 2000). Although it is not currently known from within the reserve boundaries, the Quino checkerspot butterfly is conditionally covered by the Lake Mathews Multiple Species Habitat Conservation Plan/Natural Community Conservation Plan. Several other plans that include measures to protect the Quino checkerspot butterfly are currently in development.

Section 7(a)(2) of the Endangered Species Act requires Federal agencies to consult with us prior to authorizing, funding, or carrying out activities that may affect listed species. The section 7(a)(2) consultation process is designed to ensure that Federal actions do not jeopardize the continued existence of the species and provides protection for the Quino checkerspot butterfly through reasonable and prudent measures that minimize the adverse effects of take of the species due to project impacts. For example, measures generated through formal section 7 consultation for State Route 125 South construction in the Otay Mesa area identified several activities to be undertaken, including habitat protection and restoration and a captive breeding program (U.S. Fish and Wildlife Service 1999). These activities are currently being implemented.

On April 15, 2002, we published the final designation of critical habitat for the Quino checkerspot butterfly (U.S. Fish and Wildlife Service 2002a), and it became effective May 15, 2002. Critical habitat is defined as specific areas that have been found to be essential to the conservation of the species and which may require special management considerations or protection. The primary constituent elements for Quino checkerspot butterfly occur in undeveloped areas that support various types of open-canopy woody and herbaceous plant communities. They include, but are not limited to, plant communities that provide populations of host plant and nectar sources for the Quino checkerspot butterfly. Specifically, primary constituent elements consist of:

(1) Grassland and open-canopy woody plant communities, such as coastal sage scrub, open red shank chaparral, and open juniper woodland, with host plants or nectar plants;

(2) Undeveloped areas containing grassland or open-canopy woody plant communities within and between habitat patches, utilized for Quino checkerspot butterfly mating, basking, and movement; or

(3) Prominent topographic features, such as hills and/or ridges, with an open woody or herbaceous canopy at the top. Prominence should be determined relative to other local topographic features.

With regards to designated critical habitat, section 7(a)(2) of the Endangered Species Act requires Federal agencies, including us, to ensure that actions they fund, authorize, or carry out do not destroy or adversely modify critical habitat to the extent that the action appreciably diminishes the value of the critical habitat for the survival and recovery of the species. Individuals, organizations, states, local governments, and other non-Federal entities are affected by the designation of critical habitat only if their actions occur on Federal lands, require a Federal permit, license or other authorization, or involve Federal funding.

1. Regional Planning

The San Diego Multiple Species Conservation Program (MSCP) and Multiple Habitat Conservation Program (MHCP) was initiated by local jurisdictions including the City of San Diego, County of San Diego, other cities, and private interests, and is being integrated as a component of California's Natural Community Conservation Plan Act. Implementation of the MSCP and MHCP will extend protection to many natural habitat communities in San Diego County. The Quino checkerspot butterfly is also a target species for the County of San Diego North Multiple Species Conservation Program, currently under development, which encompasses unincorporated lands east of the existing MHCP and north of the MSCP planning areas.

The MSCP encompasses approximately 236,000 hectares (582,000 acres) of southwestern San Diego County, and involves multiple jurisdictions. Approximately 69,600 hectares (172,000 acres) are targeted to be conserved within the preserve. Goals of the MSCP include: conserving listed and sensitive species, conserving biodiversity in the MSCP Plan Area, and achieving certainty in the land development process. Each take authorization holder will prepare a framework management plan to provide general direction for all preserve management issues. We and the California Department of Fish and Game approved the overall MSCP and the City of San Diego's Subarea Plan in July 1997. The City of Poway's sub-area plan was approved in 1996; the County of San Diego's in 1998; San Diego Gas and Electric in 1995; and the City of La Mesa in 2000. Other jurisdictions, including the City of Chula Vista, are expected to complete their subarea planning processes in the future. The Quino checkerspot butterfly is not a covered species for any of the sub-area plans within the MSCP, although both the County of San Diego and San Diego Gas and Electric are developing amendments to their permits to gain coverage for the Quino checkerspot butterfly. We recently awarded the State of California $10,000,000 to purchase 333 additional hectares (824 acres) of Quino checkerspot butterfly habitat in the Proctor Valley area of southwest San Diego County (Southwest San Diego Recovery Unit; see section I.G.1, Recovery Units) (U.S. Fish and Wildlife Service 2002b).

The MHCP encompasses roughly 48,118 hectares (118,852 acres) in northwestern San Diego County, and involves seven jurisdictions. This plan is still being developed, although the city of Carlsbad has proceeded ahead of the overall plan and has applied for permits from us and the California Department of Fish and Game. An estimated 8,100 hectares (20,000 acres) of land are targeted for conservation within the proposed preserve for the MHCP. The Quino checkerspot butterfly is one of the species being evaluated for incidental take coverage, however no final determination has been made at this time.

The Western Riverside Multiple Species Habitat Conservation Plan was initiated by the County of Riverside on October 8, 1998. The planning area encompasses 530,000 hectares (1.3 million acres) and is proposed to include conservation measures for 164 species, including the Quino checkerspot butterfly. Currently, 12 cities within the western portion of the County have endorsed the planning effort and will participate in the planning efforts. A draft was released for public review on November 15, 2002, and the public comment period closed on March 14, 2003. We are currently processing the permit application.

We and the California Department of Fish and Game approved the Central-Coastal NCCP in July 1996. No extant Quino checkerspot butterfly populations are known to occur within this planning area, and the species is only conditionally covered by the plan. Specifically, loss of habitat supporting populations that play an essential role in the distribution of the Quino checkerspot butterfly in the subregion and adjoining areas is not authorized by the Central-Coastal NCCP. The Central-Coastal NCCP authorizes the loss of habitat occupied by small and/or satellite populations, reintroduced populations, or populations that have expanded as a result of management actions. Should planned activities affect Quino checkerspot butterfly habitat, the Central-Coastal NCCP requires a mitigation plan be prepared that includes design modifications and other on site measures, compensation for habitat losses, and monitoring and adaptive management of the Quino checkerspot butterfly and its habitat in a manner that meets our approval.

2. San Diego National Wildlife Refuge

Habitat conservation efforts include protection of resident Quino checkerspot butterfly populations on the San Diego National Wildlife Refuge (Refuge). The Refuge was established in 1996, with the acquisition of 745 hectares (1,840 acres) at Rancho San Diego in San Diego County. The Refuge Planning Area for the Otay-Sweetwater Refuge Unit encompasses 18,605 hectares (45,974 acres) within the Southwest San Diego and Possible Future Central San Diego Recovery Units, with 31,126 hectares (7,691 acres) currently managed by the Refuge, and 21,295 hectares (5262 acres) managed by the California Department of Fish and Game. Funding for acquisition from the Land and Water Conservation Fund has remained steady at about $3 million per year. Our staff conducted Quino checkerspot butterfly surveys on the Refuge in 2001, with assistance from other certified volunteers. Surveyed locations were primarily hilltops and areas with known concentrations of host plants in the vicinity of San Miguel Mountain. Refuge surveys in 2001 resulted in expansion of the Rancho San Diego Occurrence Complex, and discovery of the Proctor Valley and Los Montañas Occurrence Complexes. Independent project-based surveys (not conducted by Service staff) in 2003 resulted in expansion of the Proctor Valley Occurrence Complex.

In addition to surveying the Refuge for the Quino checkerspot butterfly and its habitat, we are storing host plant and other native plant seeds in a seed bank for future enhancement projects. A small greenhouse is planned to produce more seed from this stock. Refuge Operating Needs System projects for Quino checkerspot butterfly habitat restoration funding have been submitted. We anticipate that future Quino checkerspot butterfly conservation efforts will increase as staff and volunteer resources grow, and new lands are acquired. Past efforts include a small enhancement project where nonnative grasses were removed, and host plant and nectar sources were planted. Research needed to identify Quino checkerspot butterfly habitat suitability and restoration methods for the Refuge is being developed.

3. Captive Propagation

Captive propagation efforts to date consist of a small population maintained by Dr. Gordon Pratt at University of California, Riverside. We are currently working with Dr. Pratt and Dr. Mike Singer to expand the program. We collected additional stock during the drought season in 2002, and are maintaining lines from five core occurrence complexes. Under the auspices of the Assessment District 161 Habitat Conservation Plan in Riverside County, the Murrieta Unified School District is building a new captive propagation facility, and we are working to establish a second captive propagation site. Butterfly "ranching" within the distribution of an extant population has been proposed in the Southwest San Diego habitat region (U.S. Fish and Wildlife Service 1999). Ranching involves wild adults that lay eggs on host plants in managed habitat; captive-hatched larvae are reared in a protected situation (B. Toon, pers. comm.).

4. California Department of Fish and Game

The California Department of Fish and Game has funded Quino checkerspot butterfly population and habitat monitoring activities using funds allocated by us under section 6 of the Endangered Species Act. Also, under the California Environmental Quality Act, an analysis of direct, indirect, and cumulative project impacts to biological resources, including the Quino checkerspot, occurs. The California Environmental Quality Act sometimes requires development and implementation of mitigation plans for projects that result in loss of habitat. The California Department of Fish and Game manages over 24,700 hectares (10,000 acres) of occupied Quino checkerspot butterfly habitat within the current MSCP preserve.

5. Government-to-Government Coordination

The Carlsbad Fish and Wildlife Office has initiated two Government-to-Government cooperation dialogues, one with the Mexican Government via a proposal submitted to the United States/Canada/Mexico Trilateral Shared Species Committee, and one with the Cahuilla Band of Indians in Riverside County. The Trilateral Committee proposal submitted in 2002, outlines research to be done on distribution of and threats to the Quino checkerspot butterfly in Baja California Norte, Mexico, focusing on areas near the international border that likely contain cross-border populations. The Cahuilla Tribal dialogue was initiated in 2002, and focused on voluntary Quino checkerspot butterfly conservation measures for the Cahuilla Indian Reservation. We have offered to assist with preparation of an environmental management plan for the Tribe, and continue to explore conservation partnership opportunities with them.

G. Recovery Strategy

The survival and recovery of the Quino checkerspot butterfly depends on protection, restoration and management of habitat within the distribution of metapopulations, augmentation of extant populations, and reintroduction or discovery of populations in areas not known to be currently occupied. Recovery efforts would also be greatly facilitated, and ongoing threats reduced, by the advent of a large-scale educational outreach program involving local cooperative partnerships. Because each extant population is unique, and their dynamics and distributions have not been studied, adaptive management practices and monitoring will be key aspects of recovery. Due primarily to the high degree of threat imposed by nonnative plant species invasion, ongoing management of all populations will be required into the foreseeable future (Foin *et al.* 1998). Habitat areas that need protection consist of all areas occupied by the butterflies, including patches of larval host plants and sites used by adults during breeding, oviposition, nectaring, and dispersal. Resilient metapopulation structure requires preservation of habitat patches that may temporarily not support larval development.

The best available information indicates the Quino checkerspot butterfly is highly endangered: it was at such low densities prior to listing that it was thought to possibly be extinct (U.S. Fish and Wildlife Service 1997a). The species is currently known from less than 25 percent of its former distribution; it is known to undergo large population fluctuations related to weather (Murphy and White 1984) (see sections I.C, Life History, and I.E.8, Climate Change), and most current populations are threatened by ongoing habitat degradation and development (see section I.E, Threats). Under current conditions, the Quino checkerspot butterfly may go extinct in the foreseeable future. Therefore, further losses of landscape connectivity within recovery units will increase the extirpation probability of extant populations and adversely affect recovery of the Quino checkerspot butterfly.

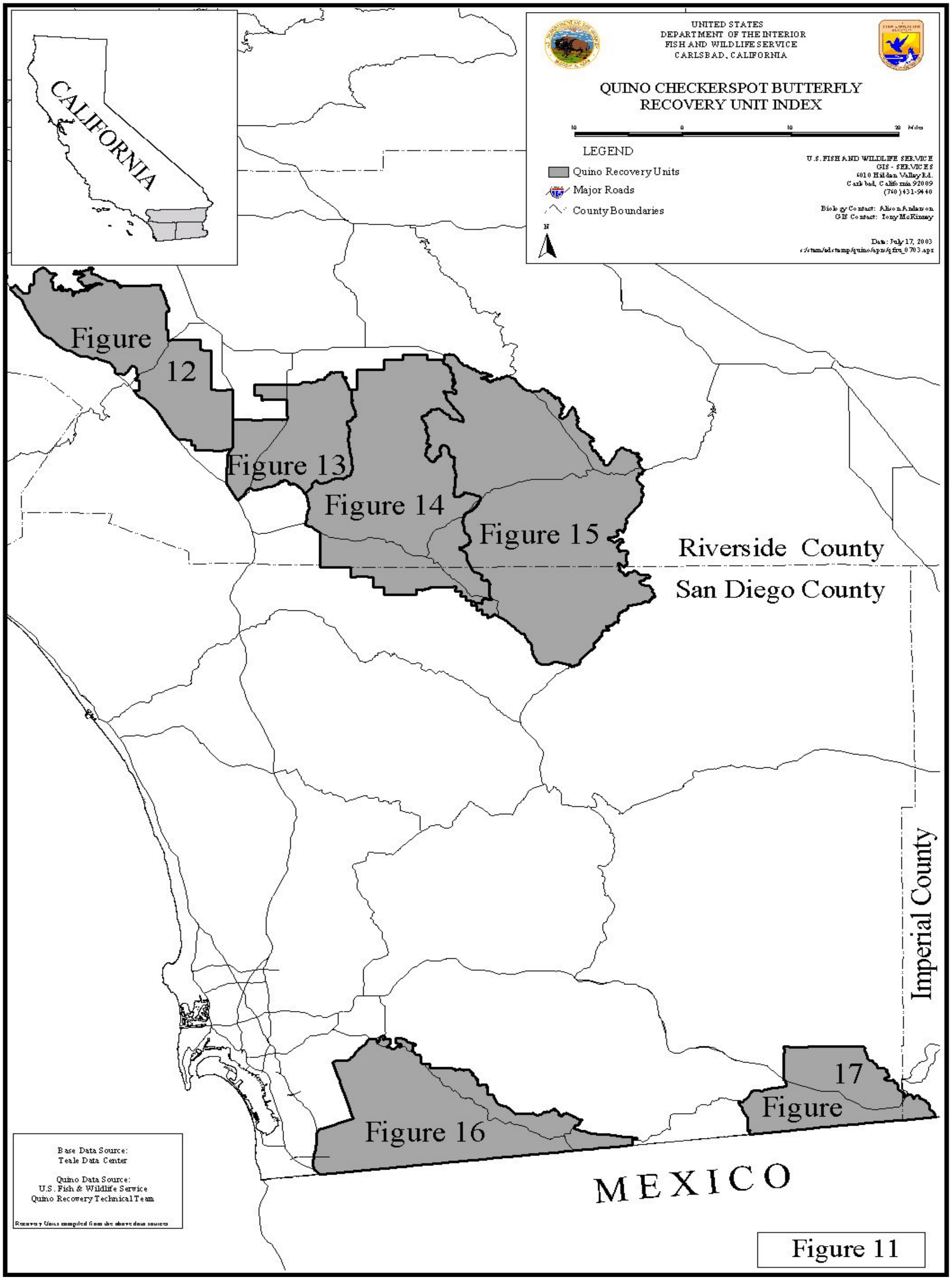
Any proposed project that might reduce the area of suitable or restorable habitat should be carefully evaluated, and conservation measures that fully protect and/or restore habitat of greater value should be outlined. Project proponents are encouraged to begin working with us in the early stages of project design to avoid and minimize project impacts and time delays. A crucial aspect of conserving existing metapopulations is the protection of dispersal areas between habitat patches, given the high degree of urbanization throughout the current range of the Quino checkerspot butterfly. Protection of landscape connectivity in a configuration that assures metapopulation resilience is essential. All habitat areas that support extant Quino checkerspot butterfly populations will require management and some degree of restoration. Restoration efforts should be guided in part by modeling efforts to predict metapopulation resilience in alternative habitat patch networks. The final management program for a particular occurrence complex or metapopulation should be preceded by:

- Creation of detailed maps of habitat patches and dispersal areas on a spatial scale that captures the essential landscape connectivity and known distribution of each populations or occurrence complex.
- Modeling of metapopulation dynamics for each occurrence complex.
- Assessment of varying restoration needs within recovery units and habitat patches.
- Identification of significant mortality sinks, such as high-traffic roads.
- Design of management tools and practices to reconstruct essential landscape connectivity and prevent dispersal into mortality sinks.
- Estimation of costs associated with alternative population management designs.

As management plans are implemented, monitoring will provide the ultimate test of effectiveness. Census surveys should be coordinated to extend over a representative sub-sample of habitat patches throughout a metapopulation distribution (see Murphy and Weiss 1988 and Recovery Criteria below), and may be combined with presence-absence surveys to determine habitat patch occupancy patterns. Collection of census data over a period of several years (approximately 15) will be required to reasonably encompass variability of current environmental conditions experienced by the species and associated density fluctuations (Murphy *et al.* 1990). Along with protecting habitat, equally high priority is assigned to establishment or discovery of at least one new, coastal population and determining the need to augment declining populations (*e.g.* the Harford Springs Occurrence Complex). The likelihood of extinction remains high unless habitat conservation (protection and management) and captive breeding programs are developed and advanced without delay.

1. Recovery Units

Recovery units identified in this recovery plan (Figures 3 and 11) are the major units for managing recovery efforts. Most recovery units contain one or more existing core (large) occurrence complexes within each habitat region. Boundaries of the Southwest San Diego, Southwest Riverside, South Riverside, and South Riverside/North San Diego Recovery Units have been modified from the draft plan (U.S. Fish and Wildlife Service 2001) to include newly discovered populations and their habitat, and/or to better reflect habitat regions described in section I D (Distribution and Habitat Considerations) above. A number of factors were considered in identifying recovery units, primarily ecological and genetic factors, political boundaries, and ongoing conservation efforts. In some instances, recovery unit boundaries were designed to maximize efficiency of reserves, encompass areas of common threats, or accommodate logistic concerns. Wherever a recovery unit shares a boundary with another recovery unit, it is crucial to maintain landscape connectivity to one or more populations in the other recovery unit in order to maintain natural metapopulation dynamics and avoid the need for costly, perpetual management. If natural landscape connectivity is not maintained, it may be necessary to undertake costly population augmentation in perpetuity in order to maintain population resilience. Recovery units may include areas of apparently suitable habitat patch networks and dispersal areas (landscape connectivity) that are not known to be occupied,


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD, CALIFORNIA
QUINO CHECKERSPOT BUTTERFLY
RECOVERY UNIT INDEX
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LEGEND
Quino Recovery Units
Major Roads
County Boundaries
N
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Date: July 17, 2003
CALIFORNIA
Figure 12
Figure 13
Figure 14
Figure 15
Riverside County
San Diego County
Imperial County
Figure 16
Figure 17
MEXICO
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Figure 11

when biological evidence warrants inclusion (*e.g.* the southern portion of the South Riverside/North San Diego Recovery Unit). Where sufficient evidence supporting inclusion of lands in recovery units is lacking, surveys and habitat assessments of possible habitat should be conducted (e.g. the eastern slope of the Santa Ana Mountains).

Biologically, Quino checkerspot butterfly recovery units include areas within which gene flow was historically, or is currently, possible. Recovery units include lands both essential and not essential to the long-term conservation of the butterfly, and comprise a variety of habitat types. Recovery unit boundaries may change if and when additional populations are documented or introduced.

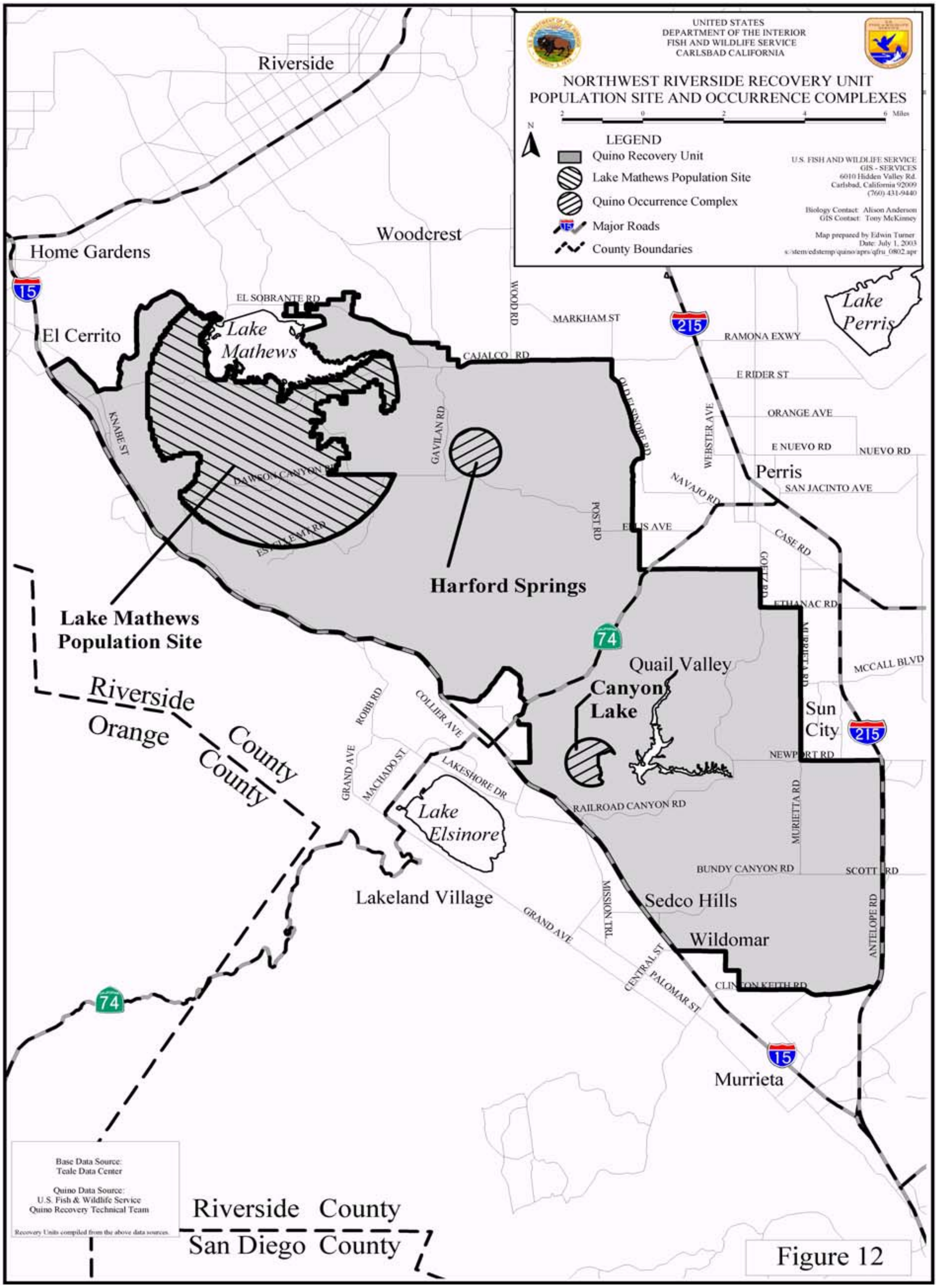
Recovery units were designed to facilitate recovery by placing the scope on a smaller spatial scale than the entire species' range, on a scale that is likely to support a megapopulation or large resilient metapopulation. Recovery units are believed to be minimum viable units, within which landscape connectivity must be maintained. Focusing recovery on smaller areas is advantageous because the three general occupied regions - western Riverside County, southwestern San Diego County, and southeastern San Diego County - are apparently isolated from one another. Thus, a narrower scope allows recovery actions to be focused on specific threats to particular habitats and encourages implementation of recovery actions by local interests. Although biological and nonbiological issues (*i.e.,* jurisdictional and logistical concerns) were considered in identifying recovery units, recovery units have a biological basis in that they are groupings of Quino checkerspot butterfly populations among which gene flow is believed to currently occur.

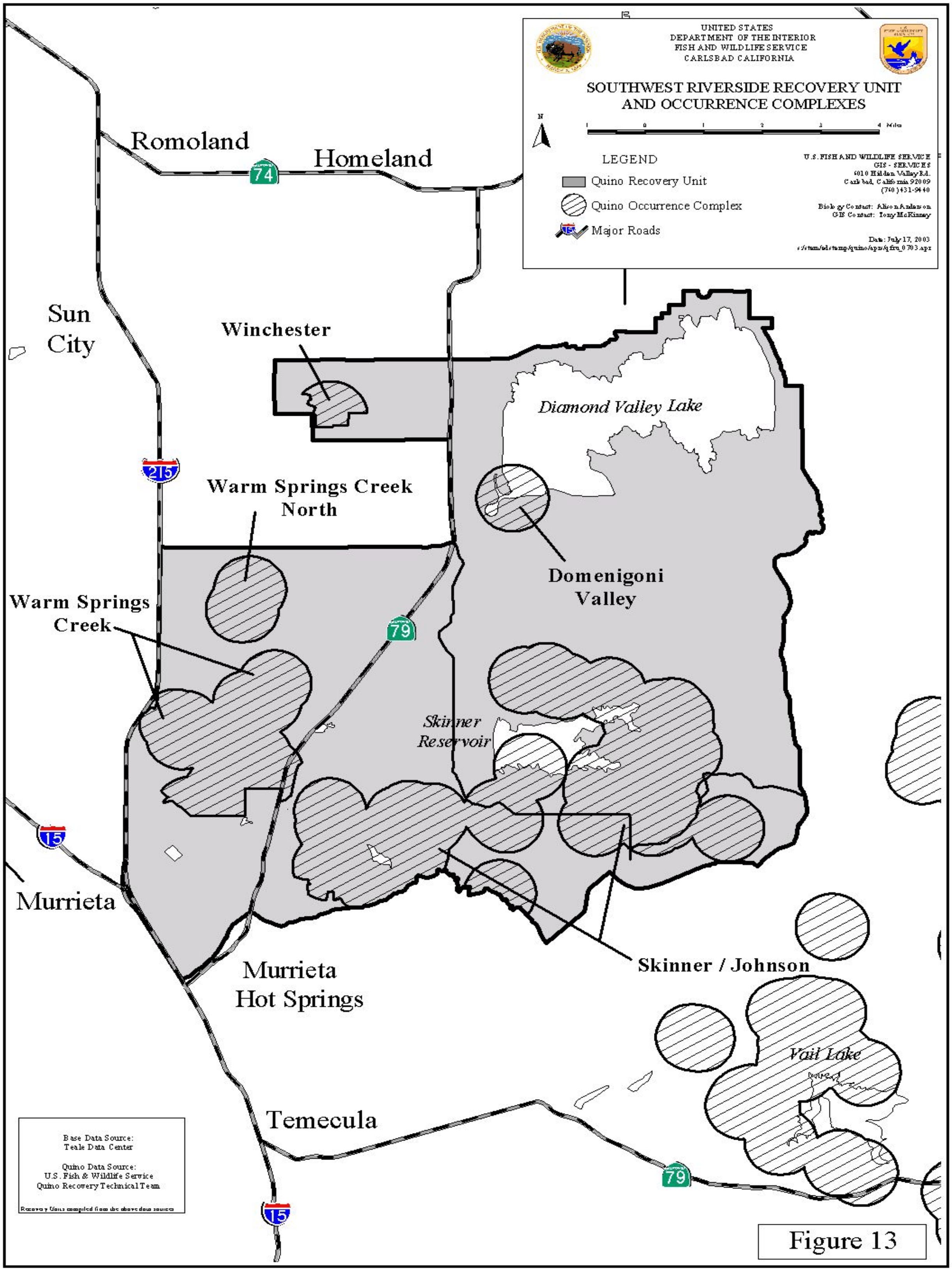
Each recovery unit is important and each is at the appropriate scale by which to gauge progress toward recovery for large-scale metapopulations (megapopulations) and the species as a whole within southern California. Recovering the Quino checkerspot butterfly within each recovery unit will maintain the overall distribution of the species throughout the remainder of their native range in the United States. Conserving populations and their habitats within recovery units should preserve genotypic diversity and allow Quino checkerspot butterflies access to diverse habitats. This maintenance of diversity is needed because a Quino checkerspot butterfly population may contain individuals adapted to the prevailing regional environmental conditions (Gilbert and Singer 1973). Individuals or local populations with an atypical genetic makeup may persist in a metapopulation in much lower abundance than those with locally adapted genes. As environmental conditions change due to natural and human-influenced processes, the survival of individuals adapted to previous conditions may no longer be enhanced. If changing environmental conditions could lead to extirpation of a population, it is possible that the area could be repopulated by individuals from another population whose survival is enhanced under the new conditions if diverse local populations are conserved. When the overall genetic diversity distributed across Quino checkerspot butterfly populations is reduced, the ability of the species to respond to changing conditions is likewise reduced, leading to a higher extinction probability. Consequently individual recovery units are necessary to the broader survival and recovery of the species. Continued survival and recovery of local populations is critical to the persistence of any metapopulations within recovery units and their role in recovery of the species.

Northwest Riverside Recovery Unit:
This recovery unit is located south of Lake Mathews, east of Interstate 15, and west of Interstate 215 as mapped (Figures 3, 11 and 12). It contains two occurrence complexes (Harford Springs and Canyon Lake) and one historically occupied population site (Lake Mathews) (Figure 12). These sites encompass what was apparently the distribution of an historically resilient metapopulation (Figure 2). The nearest recovery units are the adjacent Southwest Riverside Recovery Unit to the south, and the possible future North Orange Recovery Unit to the northwest. A degree of ecological connectivity persists throughout most of the Southwest Riverside Recovery Unit, and it is possible that some degree of landscape connectivity persists as well, at least in the northern portion.

Threats: High; primarily from habitat destruction and fragmentation due to development, and habitat degradation due to off-road vehicle activity, nonnative plant invasion, and grazing.

Southwest Riverside Recovery Unit:
This recovery unit is located in southwestern Riverside County (Figures 3, 11, and 13), east of Interstate 15 and Interstate 215, south of the town of Winchester and Scott Road, and north of urban areas in the city of Temecula as mapped. It


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
NORTHWEST RIVERSIDE RECOVERY UNIT
POPULATION SITE AND OCCURRENCE COMPLEXES
LEGEND
Quino Recovery Unit
Lake Mathews Population Site
Quino Occurrence Complex
Major Roads
County Boundaries
Riverside
Woodcrest
Home Gardens
El Cerrito
Lake Mathews
Lake Perris
Perris
Harford Springs
Lake Mathews Population Site
Quail Valley
Canyon Lake
Sun City
Riverside County
Orange County
Lake Elsinore
Lakeland Village
Sedco Hills
Wildomar
Murrieta
Riverside County
San Diego County
Base Data Source: Teale Data Center
Quino Data Source: U.S. Fish & Wildlife Service Quino Recovery Technical Team
Figure 12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SOUTHWEST RIVERSIDE RECOVERY UNIT AND OCCURRENCE COMPLEXES
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LEGEND
Quino Recovery Unit
Quino Occurrence Complex
Major Roads
U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
GIS Contact: Tony McKinney
Date: July 17, 2003
Romoland
Homeland
74
Sun City
Winchester
Diamond Valley Lake
215
Warm Springs Creek North
Domenigoni Valley
Warm Springs Creek
79
Skinner Reservoir
15
Murrieta
Murrieta Hot Springs
Skinner / Johnson
Vail Lake
Temecula
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team

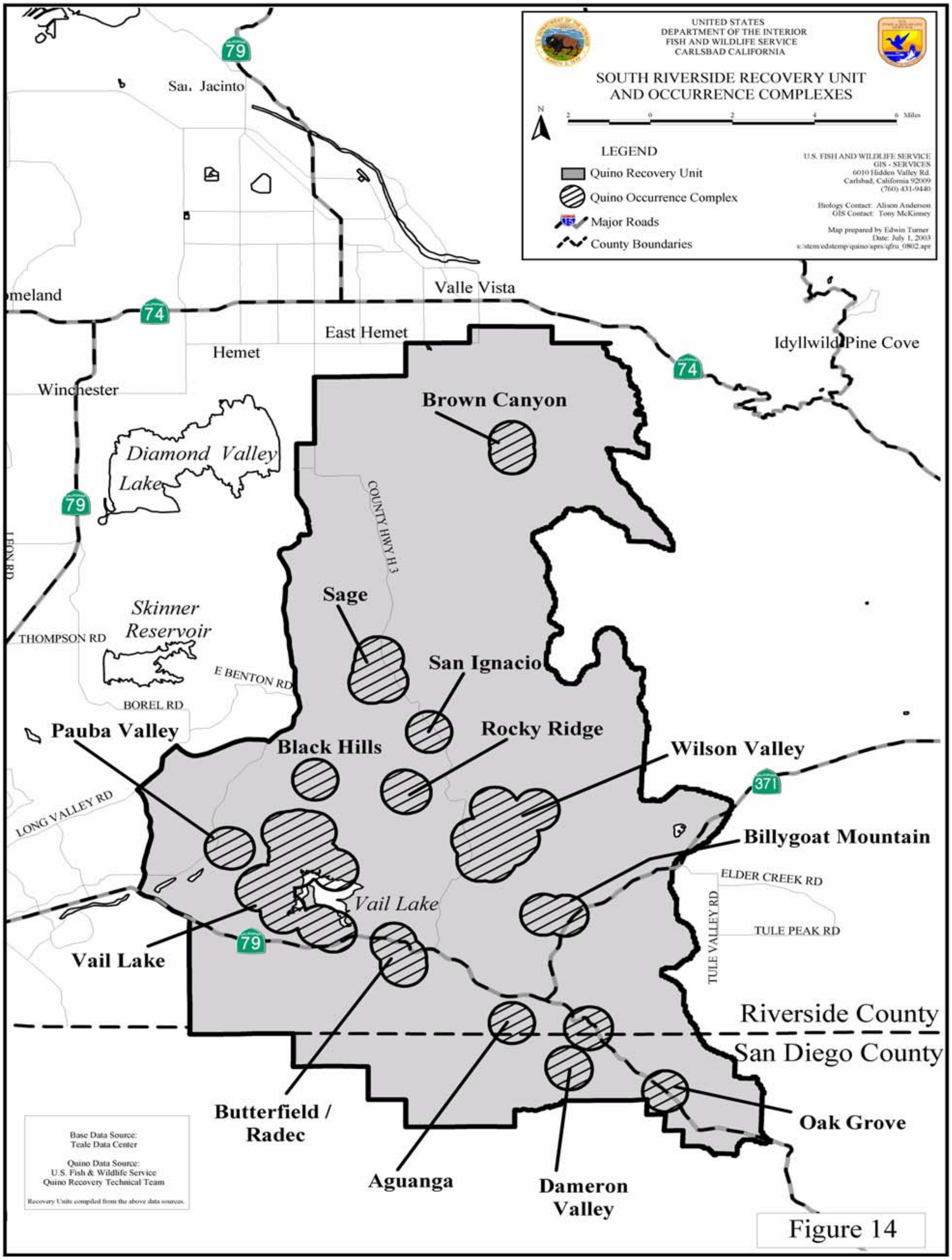
Figure 13

contains five occurrence complexes, Warm Springs Creek (core), Warm Springs Creek North, Skinner/Johnson (core), Winchester, and Domenigoni Valley (Figure 13). State Route 79 and associated development are probably a dispersal deterrent and source of mortality, but are not currently an impassable barrier between habitat patches on either side. This recovery unit is generally contiguous with the South Riverside Recovery Unit to the east. Potential ecological and landscape connectivity with the Northwest Riverside Recovery Unit are compromisedprimarily by Interstate 215 and associated development.

Threats: High; primarily resulting from habitat destruction, degradation, and fragmentation associated with development and off-road vehicle use outside of the Southwest Riverside County Multiple Species Reserve. Within the Southwest Riverside County Multiple Species Reserve nonnative plant species invasion poses the greatest threat.

South Riverside Recovery Unit:
This recovery unit is located south of State Route 74, including the Sage Road and Oak Mountain areas, on lands below 1,070 meters (3,500 feet) in elevation and north of Palomar Mountain as mapped (Figures 3, 11 and 14). This recovery unit contains 13 occurrence complexes - Pauba Valley, Black Hills, Vail Lake (core), Sage (core), San Ignacio, Rocky Ridge, Wilson Valley (core), Butterfield/Radec, Aguanga, Billy Goat Mountain, Dameron Valley, Oak Grove and Brown Canyon (Figure 14). The closest recovery units are the Southwest Riverside Recovery Unit and the South Riverside/North San Diego Recovery Unit. Landscape and ecological connectivity with the Southwest Riverside Recovery Unit to the west is threatened by increasing development. This recovery unit is contiguous with the South Riverside/North San Diego Recovery Unit and includes relatively undeveloped areas to the south including the north slope of Palomar Mountain.

Threats: High. This area is threatened by proposed development, nonnative plant invasion, off-road vehicle activity, and illegal trash dumping (G. Pratt, pers. comm.). Habitat destruction by off-road vehicle activity and dumping was particularly severe on BLM parcels where reference populations were being monitored in 2001 through 2003.


UNITED STATES
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SOUTH RIVERSIDE RECOVERY UNIT
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Quino Recovery Unit
Quino Occurrence Complex
Major Roads
County Boundaries
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GIS - SERVICES
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GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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San Jacinto
79
Valle Vista
74
East Hemet
Hemet
Winchester
Idyllwild Pine Cove
Brown Canyon
Diamond Valley
Lake
COUNTY HWY H3
Skinner
Reservoir
Lake
THOMPSON RD
E BENTON RD
BOREL RD
Sage
San Ignacio
Rocky Ridge
Pauba Valley
Black Hills
Wilson Valley
371
LONG VALLEY RD
Billygoat Mountain
ELDER CREEK RD
TULE VALLEY RD
TULE PEAK RD
Vail Lake
Vail Lake
Riverside County
San Diego County
Butterfield /
Radec
Aguanga
Dameron
Valley
Oak Grove
Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

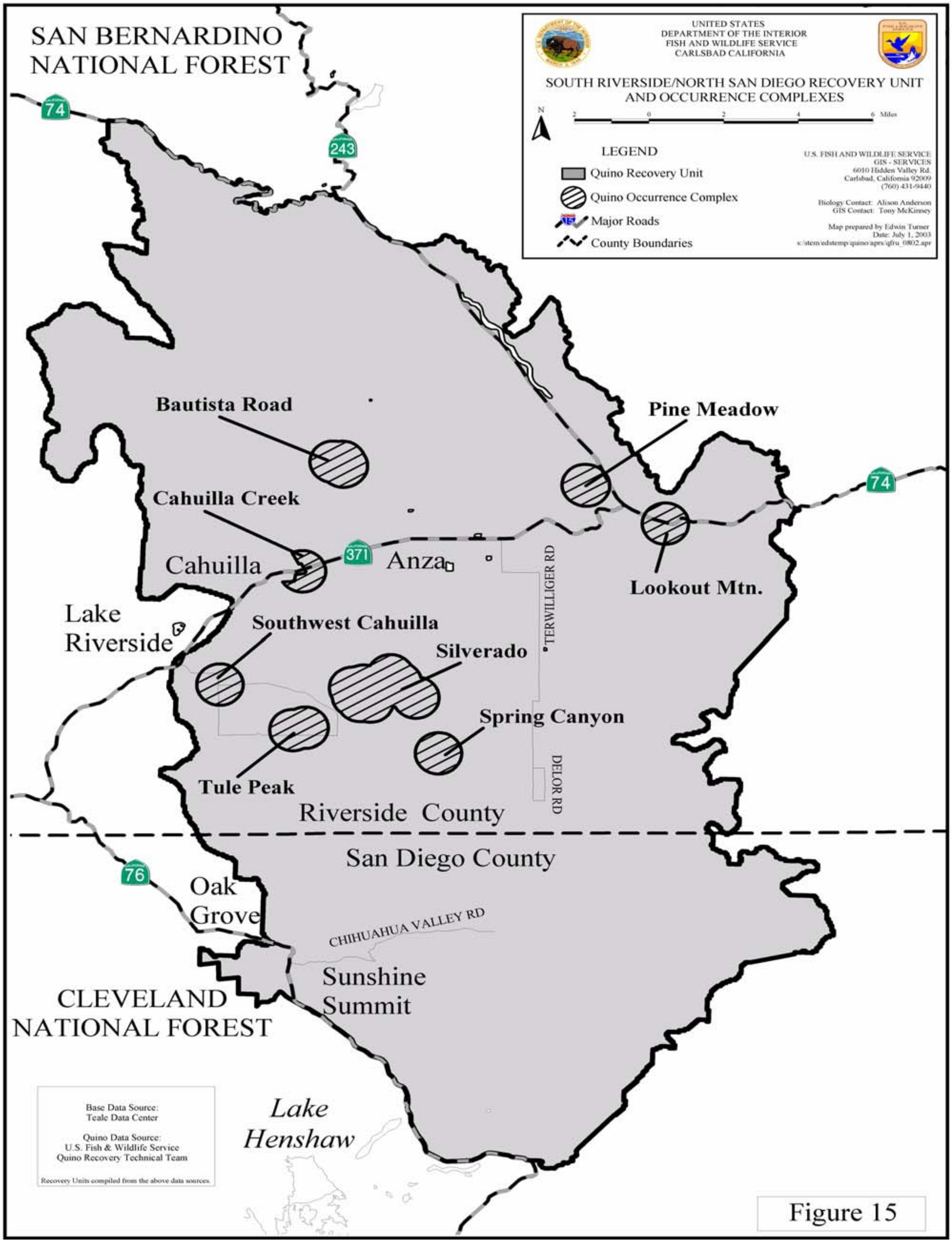
Figure 14

South Riverside/North San Diego Recovery Unit:
This recovery unit is located between 1,070 and 1,520 meters (3,500 and 5,000 feet) in elevation in Riverside and San Diego Counties, surrounding the community of Anza and the Cahuilla Indian Reservation, east of Mount Palomar, north of Warner Springs, and west of the Anza Borrego Desert as mapped (Figures 3, 11, and 15). This recovery unit contains eight occurrence complexes: Southwest Cahuilla, Tule Peak (core) , Silverado (core), Spring Canyon, Cahuilla Creek, Bautista Road, Pine Meadow, and Lookout Mountain (Figure 15). This recovery unit is contiguous with the South Riverside Recovery Unit to the west, and also has ecological connectivity with surrounding undeveloped areas.

Distribution of historic Quino checkerspot butterfly records and habitat characteristics to the south indicate the likelihood of landscape connectivity well into San Diego County. The distribution of all four primary host plants is generally continuous all the way south to the other San Diego County Recovery Units.

Threats: High; primarily off-road vehicle use, increasing development pressure (Coronado 2003), grazing, nonnative plant invasion, and fire.

Southwest San Diego Recovery Unit:
This recovery unit is located in southern San Diego County roughly south of State Route 94, east of Interstate 805 and associated urban areas, and west of the city of Tecate as mapped (Figures 3, 11 and 16). It contains 15 occurrence complexes: West Otay Mesa, Otay Valley, West Otay Mountain (core), Otay Lakes/Rancho Jamul (core), Proctor Valley, Jamul, Hidden Valley, Rancho San Diego, Los Montañas, Honey Springs, Dulzura, Marron Valley (core), Barrett Junction, and Tecate (Figure 16). The closest recovery units are the possible future Central San Diego Recovery Unit to the north and the Southeast San Diego Recovery Unit to the east. There may be some degree of landscape connectivity to the possible future Central San Diego Recovery Unit through undeveloped lands in central portions of the county. Eastern landscape connectivity has been compromised by development associated with the towns of Tecate and Campo. There may also be connectivity to the Southeast San Diego Recovery Unit through lands in Baja California, Mexico, and through undeveloped land north of State Route 94. Currently, State Route 94 is limited


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
SOUTH RIVERSIDE/NORTH SAN DIEGO RECOVERY UNIT AND OCCURRENCE COMPLEXES
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Quino Recovery Unit
Quino Occurrence Complex
Major Roads
County Boundaries
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GIS - SERVICES
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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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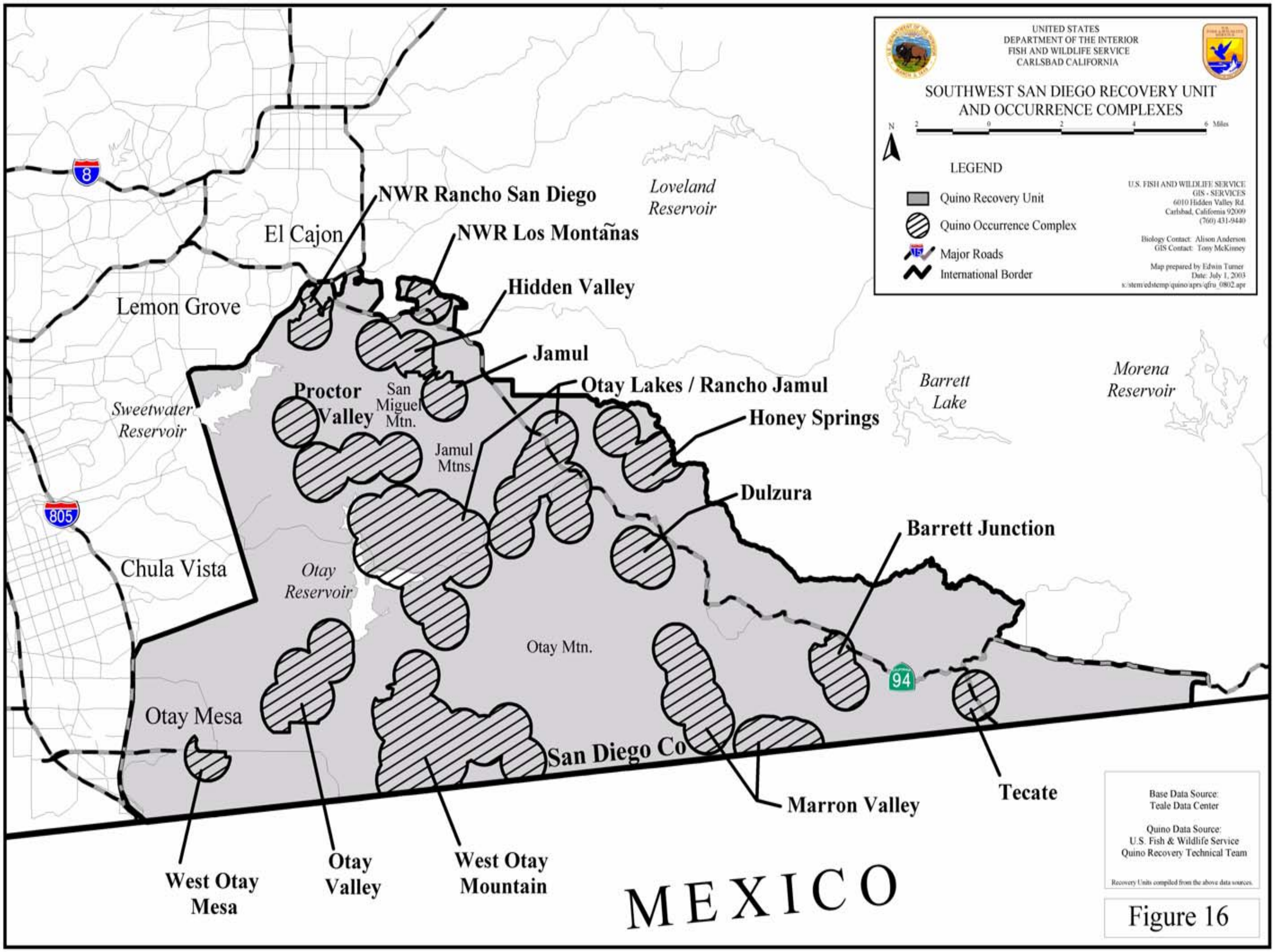
SAN BERNARDINO NATIONAL FOREST
74
243
Bautista Road
Pine Meadow
Cahuilla Creek
371
Cahuilla
Anza
Lookout Mtn.
TERWILLIGER RD
Lake Riverside
Southwest Cahuilla
Silverado
Spring Canyon
Tule Peak
DELOR RD
Riverside County
San Diego County
76
Oak Grove
CHIHUAHUA VALLEY RD
Sunshine Summit
CLEVELAND NATIONAL FOREST
Base Data Source: Teale Data Center
Quino Data Source: U.S. Fish & Wildlife Service Quino Recovery Technical Team
Recovery Units compiled from the above data sources.
Lake Henshaw
Figure 15


UNITED STATES
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CARLSBAD CALIFORNIA
SOUTHWEST SAN DIEGO RECOVERY UNIT
AND OCCURRENCE COMPLEXES
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Quino Recovery Unit
Quino Occurrence Complex
Major Roads
International Border
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GIS - SERVICES
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Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
NWR Rancho San Diego
NWR Los Montañas
Hidden Valley
Jamul
Otay Lakes / Rancho Jamul
Honey Springs
Dulzura
Barrett Junction
Proctor Valley
San Miguel Mtn.
Jamul Mtns.
Loveland Reservoir
Barrett Lake
Morena Reservoir
El Cajon
Lemon Grove
Sweetwater Reservoir
Chula Vista
Otay Reservoir
Otay Mtn.
Otay Mesa
San Diego Co
West Otay Mesa
Otay Valley
West Otay Mountain
Marron Valley
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8
805
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Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

Figure 16

to two lanes in that area, and does little to compromise Quino checkerspot butterfly dispersal ability.

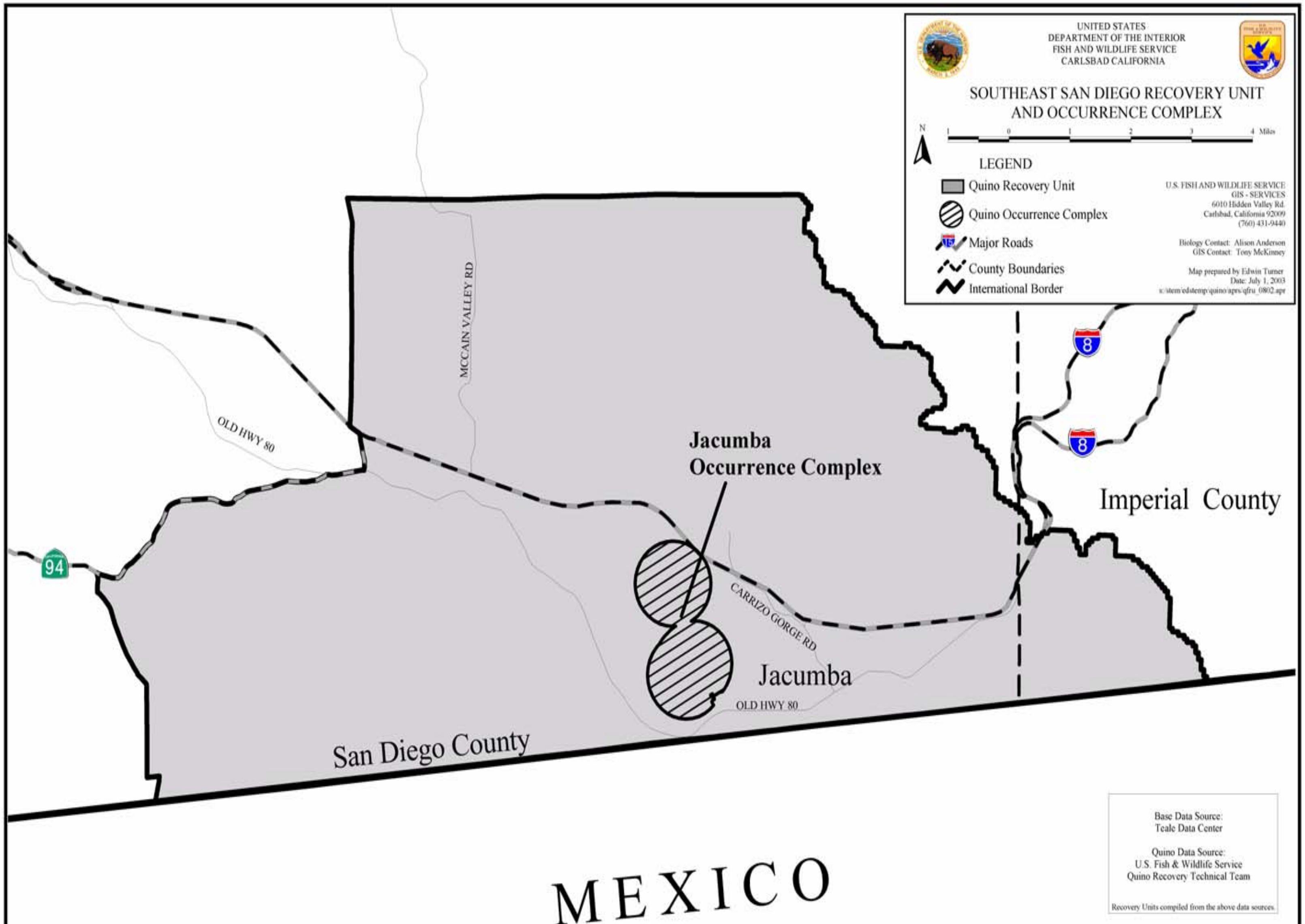
Threats: High; primarily habitat destruction, degradation, and fragmentation associated with development in the western areas. Most historic coastal habitats have been destroyed and/or isolated by development (*e.g.* Dictionary Hill). Remaining occupied habitat areas continue to be threatened by encroaching development and ongoing agriculture, grazing, road grading, and off-road vehicle and Border Patrol activities. These disturbances have also resulted in, and continue to exacerbate, nonnative plant invasion problems.

<u>Southeast San Diego Recovery Unit</u>:
The location of this recovery unit is centered around the town of Jacumba in southeastern San Diego County, east of the Imperial County line and north of the International Border, south of State Route 94 and east of Campo as mapped. This recovery unit also includes the Table Mountain area north of Interstate 8, McCain Valley, and a small area in Imperial County (Figures 3, 11, and 17). It contains the Jacumba Occurrence Complex (Figure 17). The closest other recovery unit is the Southwest San Diego Recovery Unit; landscape connectivity between them is compromised primarily by development in the Tecate and Campo areas. There is ecological, and possibly landscape, connectivity with the South Riverside/North San Diego Recovery Unit to the north along the western slope of the Laguna Mountains.

Threats: Low; primarily habitat destruction, degradation, and fragmentation associated with development, and off-road vehicle use.

2. Possible Future Recovery Units

The three possible future recovery units described below include areas that are considered suitable to sustain the populations outside of current recovery units specified by Recovery Criterion 5 (see section II.B below). The Possible Future Central San Diego Recovery Unit contains two occurrence complexes necessary to meet Recovery Criteria 1 to 3, and provides at least one of the two additional populations specified by Recovery Criterion 5 in the Draft Quino Checkerspot Butterfly Recovery Plan (U.S. Fish and Wildlife Service 2001). Although two of the possible future recovery units do not appear to be currently occupied by the


UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
CARLSBAD CALIFORNIA
SOUTHEAST SAN DIEGO RECOVERY UNIT
AND OCCURRENCE COMPLEX
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LEGEND
Quino Recovery Unit
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Major Roads
County Boundaries
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U.S. FISH AND WILDLIFE SERVICE
GIS - SERVICES
6010 Hidden Valley Rd.
Carlsbad, California 92009
(760) 431-9440
Biology Contact: Alison Anderson
GIS Contact: Tony McKinney
Map prepared by Edwin Turner
Date: July 1, 2003
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Base Data Source:
Teale Data Center
Quino Data Source:
U.S. Fish & Wildlife Service
Quino Recovery Technical Team
Recovery Units compiled from the above data sources.

Figure 17

Quino checkerspot butterfly, they either historically supported populations (Figure 2), or are within the greater historic range and appear to have a high potential to support managed metapopulations based on general habitat characteristics. The possible future recovery units are within the only remaining large undeveloped coastal areas of Orange and San Diego Counties, but research is needed to determine the extent and location of undocumented populations, or suitable or restorable habitat for reintroduction. Although unlikely, it is possible that occupied or restorable habitat patch networks with a marine climate influence may be identified partially or entirely outside the areas described below. Well-managed coastal preserves in San Diego or Orange County may be able to support resilient populations of the Quino checkerspot butterfly.

Possible Future Central San Diego Recovery Unit:

This possible future recovery unit in San Diego County includes vernal pool habitat on Kearny Mesa, Mira Mesa, Del Mar Mesa, and Lopez Ridge. The unit also includes inland habitat in the vicinity of Sycamore and Little Sycamore Canyons, Iron Mountain, San Vicente Reservoir, the Fortuna Mountain area, El Capitan Reservoir, the community of Alpine, and south to the Southwest San Diego Recovery Unit border near the community of Jamul. As an alternative, this unit as described could be split into two units based on coastal climate influence, or part of this unit as described could be included in an expansion of the Southwest San Diego Recovery Unit. There are historic records of Quino checkerspot butterflies scattered throughout this recovery unit. Occupancy was documented in 2001 after the draft recovery plan (U.S. Fish and Wildlife Service 2000) was published, in the northeastern section near San Vicente Reservoir (San Vicente Occurrence Complex; Sproul and Faulkner 2001), and south of the community of Alpine in 2003 (Alpine Occurrence Complex; Lee 2003, Figure 8). Pending further analysis of areas for inclusion in this recovery unit (based on further habitat and butterfly surveys) and opportunity for public review, we intend to propose this possible future recovery unit as one or more recovery units in an addendum to this recovery plan.

This possible future recovery unit contains high-quality, historic habitat of the Quino checkerspot butterfly similar to the historic condition of Otay Mesa (see Murphy and White 1984). Recent surveys reported cryptogamic crusts and vernal pool complexes supporting extensive *Plantago erecta* stands on mesa tops east of Interstate 805 (Osborne 2000). Marine climate influence should help protect larval food plants from heat and drought, thus increasing host plant abundance and suitability, and allowing higher rates of pre-diapause larval survival than in more climatically variable inland regions (see section I.C, Life History).

The general ecological description of the southwestern San Diego County region above also describes this possible future recovery unit. The mesa areas contain relatively high quality vernal pool and mima mound habitat patches on predominantly red clay soils. Habitat areas in the eastern portions of this unit contain cryptogamic crusts and dense patches of *Plantago erecta* mixed with abundant *Castilleja exserta*. In northeastern areas of this recovery unit, apparently suitable Quino checkerspot butterfly habitat can be found distributed extensively across open ridge tops of mixed chaparral/coastal sage scrub. In 2001, occupied habitat north of San Vicente Reservoir contained *P. erecta*, *Cordylanthus rigidus*, *C. exserta*, and abundant nectar sources (A. Anderson, pers. observ.). Ridge top habitat in the eastern portions of the possible future recovery unit can be difficult to detect and access because surrounding slopes are sometimes covered with dense chaparral. However, such relatively narrow zones (several meters) of closed-canopy chaparral are not considered to pose a barrier to Quino checkerspot butterfly dispersal (K. Osborne, G. Pratt, C. Parmesan, and M. Singer, pers. comm.). Satellite imagery indicates that habitat from the town of Alpine south to State Route 94 still has landscape connectivity. Large potential habitat patches have been reported in the vicinity of Sycuan Peak (R. Riggin 2003), and it is possible that extant Quino checkerspot butterfly populations may exist in that area south of the Alpine Occurrence Complex (Figure 8). Collection records of *Antirrhinum coulterianum* indicate populations of that host plant exist throughout the unit (Thompson 1988).

The possible future Central San Diego Recovery Unit is designed to provide landscape connectivity within the least developed coastal and inland mesas and foothills of San Diego County, and is entirely within the San Diego County Multiple Species Habitat Planning Area. Landscape connectivity within a network of otherwise suitable or restorable habitat patches has been compromised by Interstates 5, 805, 8, and 15; State Routes 52 and 67; and development in Mira Mesa, Rancho Penasquitos, Scripps Miramar Ranch, and Alpine. Restoration of landscape connectivity (or the equivalent) in westernmost portions of the possible future recovery unit would require either technological solutions, or active management in perpetuity. The possibility of landscape connectivity with recovery units to the north and east depends on protection of open space and enhancement of landscape connectivity in the vicinity of State Route 67, San Vicente Reservoir, Iron Mountain, and south and east of the town of Alpine. To the maximum extent possible, the ecological connectivity of this recovery unit to northern and eastern natural areas should also be maintained to prevent isolation, retain possible landscape connectivity with the northern range of the species, and decrease the need for active management.

<u>Possible Future Northwest San Diego Recovery Unit</u>:

This possible future recovery unit encompasses portions of northwestern San Diego and southern Orange Counties, including Marine Corps Base Camp Pendleton and adjacent reserve lands and undeveloped areas. No records of the Quino checkerspot butterflies are known from this possible future recovery unit; however, it has characteristics of other habitats that historically supported high densities of the species in southwestern San Diego County, as described by Murphy and White (1984). Historic Quino checkerspot butterfly collection records near the possible future recovery unit, northwest in Dana Point, and south in Vista, suggest this possible future recovery unit was formerly occupied (Figure 2) (see section I.D, Distribution and Habitat Considerations). Records exist for *P. erecta* (Rahn 1979), *A. coulterianum* (Thompson 1988) and *C. rigidus* (Chuang and Heckard 1986) collections within this possible future recovery unit.

The lack of historical Quino checkerspot butterfly records on Camp Pendleton is to be expected; access has always been limited, and Camp Pendleton has been restricted to amateur biological collectors since its establishment in 1942. Camp Pendleton management contracted for a general base-wide habitat survey in 1996 and 1997, as well as several subsequent site-specific butterfly surveys (Redak 1998). Surveyors stated they found abundant "optimal and adequate Quino checkerspot butterfly habitat;" however, surveyors did not detect butterflies, and did not conduct comprehensive surveys base-wide (Redak 1998).

Huerero soils and clay lenses support vernal pools on coastal terraces in the western portion of this possible future recovery unit. Historically, the coastal terrace area also supported mima mounds and vernal pools. Although most vernal pool topography has been degraded or destroyed, it is restorable (M. Dodero, pers. comm.). Other topographic features indicative of Quino checkerspot butterfly habitat include mesas, rolling hills, and ridge lines. Vegetation consists of mixed coastal sage scrub and chaparral, with grassland inclusions. Although *Plantago erecta* is abundant in patches (Redak 1998, Osborne 2000), the full extent of Quino checkerspot butterfly host plant distribution within the possible future recovery unit is unknown. Quino checkerspot butterfly nectar plants are also abundant (Redak 1998, Osborne 2000). Similar to the Southwest San Diego Recovery Unit, this possible future recovery unit should provide a more stable marine climate influence. Amelioration of hot, dry climatic conditions and its diverse, largely undeveloped topography should make the possible future Northwest San Diego Recovery Unit a crucial one with regard to climate change (see section I.C, Life History).

Efforts to restore habitat or establish experimental populations of the Quino checkerspot butterfly could be undertaken on the coastal terrace from the Santa Margarita River north to San Mateo Creek. The interior of the recovery unit should be surveyed for Quino checkerspot butterfly habitat and occupancy. The coastal sage scrub and mixed chaparral of Camp Pendleton and the area where Orange, Riverside, and San Diego Counties intersect have interstitial native grasslands that could currently harbor the species, or be suitable as reintroduction sites.

The closest recovery units are the Southwest Riverside Recovery Unit to the east, and the possible future North Orange Recovery Unit to the north. There may be landscape connectivity to the eastern slope of the Santa Ana Mountains, particularly through the lower Santa Margarita River watershed, however, no habitat surveys have been done. Murphy and Bomkamp (1999) found small patches of *Plantago* scattered across the southern sub-region of Orange County, including the transportation corridor option. Murphy and Bomkamp (1999) concluded that resources are currently insufficient to support Quino checkerspot butterfly populations, but that restoration potential exists. However, subsequent to Murphy and Bonkamp's study, new species of primary host plants have been documented, and these species are found in the Santa Ana Mountain foothills (*e.g. Antirrhinum coulterianum*, see Thompson 1988). The western slope of the Santa Ana Mountains appears to hold the possibility of landscape connectivity with the possible future North Orange Recovery Unit and would include land in and along the lower elevation portions of the U.S. Forest Service's Cleveland National Forest. Ecological and landscape connectivity could be achieved by using public open space areas such as the Limestone Canyon Regional Park site, Whiting Ranch Wilderness Park, Oneill Regional Park, and Ronald W. Caspers Wilderness Park. This landscape connectivity could be further enhanced using private lands associated with the National Audubon Society Starr Ranch Sanctuary, Rancho Mission Viejo Land Conservancy and land in the Foothill Trabuco area.

<u>Possible Future North Orange Recovery Unit</u>:

This possible future recovery unit is located on the northern slope of the Santa Ana Mountains in Orange County, including the areas around Irvine Lake, Black Star Canyon, Gypsum Canyon, Fremont Canyon, Baker Canyon, Weir Canyon, Coal Canyon, Windy Ridge, Upper Blind Canyon and all intervening ridge lines. This possible future recovery unit is located west of the Riverside/Orange County line and north of the Loma Ridge-Limestone Canyon area. The area around Irvine Park is the site of a historically dense Quino checkerspot butterfly population (Orsak 1978, Figure 2). Quino checkerspot butterfly occupancy was last documented in Orange County in 1967, at a site in the northern Santa Ana Mountains called Black Star Canyon (Figure 2), but was apparently extirpated by a fire the same year (Orsak 1978). Informal private reintroduction efforts using Quino checkerspot butterflies from the Gavilan Hills, Riverside County, were conducted there in 1974 (Orsak 1978), however, it is not known if any of the transplanted butterflies released in 1974 established occupancy. Most of the canyons have been historically poorly surveyed for wildlife. Recently, the Irvine Company transferred title of the "Fremont Conservation Area" (a large portion of this possible future recovery unit) to The Nature Conservancy.

The Irvine Park area does not appear to support sustainable resources due to habitat degradation, and restoration is needed before Quino checkerspot butterfly metapopulations can be reestablished (D. Murphy, pers. comm.).

However, the diverse, unfragmented montane topography in much of this possible future recovery unit makes the area a good candidate to support a reintroduced population (see section I.C, Life History).

II. RECOVERY

A. Objectives

The overall objective of this recovery plan is to reclassify the Quino checkerspot butterfly from endangered to threatened status and ensure the species' long-term conservation. Interim goals include: (1) protecting habitat supporting known current population distributions (occurrence complexes) and landscape connectivity between them; (2) maintaining or creating resilient populations; and (3) conducting research necessary to refine recovery criteria. Reclassification to threatened status is appropriate when a taxon is no longer in danger of extinction throughout a significant portion of its range. Because data upon which to base reclassification decisions are incomplete, downlisting criteria in this plan are necessarily preliminary. There are insufficient data on which to base delisting criteria at this time; research tasks necessary to develop appropriate delisting
criteria are identified in the Recovery Action Narrative below (section II.C).

B. Recovery Criteria

1) Permanently protect the habitat within occurrence complexes (estimated occupied areas based on butterfly occurrences; see section I.D, Distribution and Habitat Considerations), including larval host plants, adult nectar resources, hilltops, and dispersal areas and landscape connectivity between occurrence complexes in a configuration designed to support resilient populations. One or more occurrence complexes may belong to a single greater population distribution, or an occurrence complex may contain more than one whole or partial population distribution. When population distributions are determined by future research or delineated by development and reserve boundaries, the population distribution will replace the occurrence complex as the protected unit.

Recovery units and included occurrence complexes described in this recovery plan are:

- Northwest Riverside Recovery Unit, containing the Harford Springs and Canyon Lake Occurrence Complexes;
- Southwest Riverside Recovery Unit, containing the Warm Springs Creek (core), North Warm Springs Creek, Winchester (but see Action 1.2 below), Domenigoni Valley, and Skinner/Johnson (core) Occurrence Complexes;

- South Riverside Recovery Unit, containing the Pauba Valley, Black Hills, Vail Lake (core), Sage (core), San Ignacio, Rocky Ridge, Wilson Valley (core), Butterfield/Radec, Aguanga, Billy Goat Mountain, Dameron Valley, Oak Grove and Brown Canyon Occurrence Complexes;
- South Riverside/North San Diego Recovery Unit, containing the Southwest Cahuilla, Tule Peak (core), Silverado (core), Spring Canyon, Cahuilla Creek, Bautista Road, Pine Meadow, and Lookout Mountain Occurrence Complexes;
- Southwest San Diego Recovery Unit, containing the Rancho San Diego, Los Montañas, Hidden Valley, Jamul, Proctor Valley, Otay Lakes/Rancho Jamul (core) , Honey Springs, Dulzura, Barrett Junction, Marron Valley (core), Tecate, West Otay Mountain (core), Otay Valley, and West Otay Mesa Occurrence Complexes;
- Southeast San Diego Recovery Unit, containing the Jacumba Occurrence Complex; and
- San Vicente and Alpine Occurrence Complexes (Possible Future Central San Diego Recovery Unit).

2) Conduct research including: determine the current short-term and potential long-term distributions of populations and associated habitat; conduct preliminary modeling of metapopulation dynamics for core occurrence complexes identified in section I.D, Distribution and Habitat Considerations; investigate the dispersal and colonization potential of the Quino checkerspot butterfly (including genetic relationships among populations), investigate the function of hilltops as a resource for Quino checkerspot butterfly populations; investigate the contribution of multiple-year diapause to population resilience; monitor populations for further evidence of local decline; determine the effects of elevated atmospheric carbon dioxide, nitrogen fertilization, and invasive plants on the Quino checkerspot butterfly and its host plant; conduct studies to determine the magnitude of threats from over-collection and natural enemies.

3) Permanently provide for and implement management of occurrence complexes (or population distributions when delineated) to restore or enhance habitat quality and population resilience, including enhancement of host plant populations, enhancement of diverse nectar sources and pollinators, control of nonnative plant invasion, and enhancement of landscape connectivity. Management should be

implemented as described in Recovery Action 1 (section II.C below, Recovery Action Narrative).

4) The protected, managed population segments within core occurrence complexes (or population distributions when delineated) must demonstrate evidence of resilience. Evidence of resilience is demonstrated if over a period of at least 10 and not more than 20 years, a decrease in the number of occupied habitat patches within an occurrence complex (or population distribution when delineated) is followed by increases of equal or greater magnitude. This monitoring period must begin in the third of three years with favorable climate (total annual January and February precipitation within one standard error of the average total for those months over the past 30 years [1974 to 2003], based on local or proxy climate data). Sample size should be determined using appropriate science, including information on metapopulation dynamics, patch size, relative patch distribution, and modeling. The surveyed sample of habitat patches should be spatially distributed as evenly as possible to avoid error due to correlation of suitability among nearby patches. Population viability models or equivalent modeling that provides evidence of resilience may be substituted for the above described monitoring if such a model undergoes independent peer review by at least three modeling experts and is deemed valid both by us and reviewers (including Quino checkerspot butterfly experts). The 10 to 20-year time period is based on the apparent 10- to 20-year natural population density/distribution cycles of the Quino checkerspot butterfly. If populations do not demonstrate resilience over a 10 to 20-year period, then augmentation should be implemented as in Recovery Action 1 and the 10 to 20 year monitoring period should be reinitiated. However resilience should still be evaluated with reference to the original starting point to ensure that long-term declining trends are not disregarded.

5) One additional population should be documented or introduced within the Lake Matthews population site (formerly occupied, not known to be currently occupied) in the Northwest Riverside Recovery Unit. At least one of the extant populations outside of current recovery units (*e.g.* the San Vicente Reservoir Occurrence Complex) must meet resilience specifications above unless an additional population is established or documented within 10 kilometers (6 miles) of the ocean (a more stable marine climate influence should minimize susceptibility to drought and reduce probability of extirpation).

6) Establish and maintain a captive propagation program for maintenance of representative refugia populations, research, and reintroduction and augmentation of wild populations as appropriate. Genetic stock from populations throughout the current range of the species should be maintained at two separate, independent facilities. Captive propagation may include on-site butterfly ranching in habitat if augmentation or reintroduction is deemed necessary. Any population augmentation must be followed by monitoring.

7) Initiate and implement a cooperative outreach program targeting areas where Quino checkerspot butterfly populations are concentrated in western Riverside and southern San Diego Counties.

Downlisting of the Quino checkerspot butterfly is conditioned on the above criteria and the rules set forth under section 4 of the Endangered Species Act. In making any downlisting determination we will consider the following: (1) present or threatened destruction, modification, or fragmentation of its habitat or range; (2) invasion of non-native plant and animal species; (3) over-collection by hobbyists and dealers; (4) off-road vehicle use and other recreational activities; (5) detrimental fire management practices; and (6) anthropogenic global change factors (*i.e.,* enhanced nitrogen deposition, elevated atmospheric carbon dioxide concentrations, and climate change).

C. Recovery Action Narrative

Priorities rankings were assigned as follows:
1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
2 - An action that must be taken to prevent a significant decline in species' population, habitat quality, or some other significant negative impact short of extinction.
3 - All other actions necessary to meet the recovery objectives.

Priority 1 Recommendations:

1. Protect (via acquisition, conservation easement, or other means) habitat patches and dispersal areas within and between mapped occurrence complexes, and provide ongoing management to enhance habitat and maintain or create resilient populations. Protection will primarily be accomplished through regional multiple species plans and Habitat Conservation Plans. *Euphydryas editha* requires relatively large areas of conserved landscape connectivity to maintain populations, whether they are diffusely distributed well-mixed populations, or metapopulations. Maintenance of dispersal areas linking a network of habitat patches across the greater landscape will be required to conserve resilient Quino checkerspot butterfly metapopulations. Ecological connectivity of land supporting Quino checkerspot butterfly populations with adjacent undeveloped lands, even if they do not contain potential habitat, should remain intact whenever possible. Such lands are likely to contain landscape connectivity essential to other species that are part of the ecological community supporting Quino checkerspot butterfly populations, such as pollinators, higher predators (that control butterfly predators), and woody plant species. Areas of interface between developed and undeveloped lands will require ongoing active management to reduce direct and indirect impacts of development on fragmented wild lands, such as nonnative plant invasion and off-road vehicle activity. Management should also include measures to reduce movement of butterflies into developed areas, especially those known to be sources of mortality, such as roads.

An increase in efforts to enhance the suitability of habitat patches within an occurrence complex (or population distribution, when delineated) should be implemented if a decline in the number of butterflies observed in monitored, occupied habitat patches is documented during 2 consecutive years of total annual January and February precipitation within one standard error of the average total for those months over the past 30 years (based on local or proxy climate data). Management should be adaptive: i.e., ongoing surveys, monitoring, and research (to determine habitat suitability, appropriate butterfly population status indices, and delimit temporal and geographic patterns of Quino checkerspot butterfly movement) should be conducted and management strategies refined accordingly.

If the population is determined not to be resilient based on the number of occupied habitat patches (as specified in Recovery Criterion 4 above) after 20 years of monitoring, then population augmentation should be implemented. If no occupancy is documented within an entire occurrence complex or population distribution (not a local population within a metapopulation) for 3 consecutive years, reintroduction from captive stock and evaluation of reasons for decline including but not limited to standard measures of habitat quality (e.g. pesticide contamination) should be initiated, and an intensified level of management and monitoring maintained until resilience is achieved.

1.1. Northwest Riverside Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat that is part of the known historic Gavilan Hills/Lake Mathews population distribution (including the Lake Matthews population site and the Harford Springs Occurrence Complex), in a configuration designed to support a resilient metapopulation. Develop an integrated, comprehensive Quino checkerspot butterfly management plan for the Lake Mathews/Estelle Mountain Preserve. Include as much habitat associated with the Canyon Lake Occurrence Complex as possible in the reserve.

1.2. Southwest Riverside Recovery Unit: Protect as much as possible of the remaining undeveloped suitable and restorable habitat that is part of the known population distributions in a configuration designed to support resilient metapopulations. Develop an integrated, comprehensive Quino checkerspot butterfly management plan for Southwest Riverside County Multiple Species Reserve and an additional reserve in the vicinity of Warm Springs Creek between Interstate 215 and State Route 79 to preserve dynamics of the existing populations. Current needs include continued reserve expansion, especially in the Warm Springs Creek area. Off-road vehicle and other recreational activity disturbance on public land and in dedicated preserve/mitigation areas should be reduced. Dispersal areas are in particular need of protection in this recovery unit, because of the high degree of fragmentation due to development. Population augmentation (e.g. ranching) will probably be needed in the Warm Springs Creek area, although habitat mapping and monitoring must first be conducted. The Winchester occurrence complex may already be extirpated; if it is determined that this occurrence complex is not extant and/or viable it should be excluded from Recovery Criterion 1.

1.3. South Riverside Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within and between the occurrence complexes. A particular management need is reduction of off-road vehicle and other recreational activity disturbance on public land and in pre-approved mitigation areas in the vicinity of the Oak Mountain and Wilson Valley Occurrence Complexes. Protection needs include maintenance of landscape connectivity between the core Skinner/Johnson and Sage Occurrence Complexes, and within the landscape connectivity bottleneck in the vicinity of the Billygoat Mountain Occurrence Complex. This "landscape connectivity bottleneck" between the towns of Aguanga and Anza is caused by development associated with the towns and State Routes 79 and 371, and ecologically by the vegetation and topography of Palomar Mountain to the south and Cahuilla Mountain to the north.

1.4. South Riverside/North San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable linked habitat patches and dispersal areas within and between the occurrence complexes. Of particular concern is protection of land within and between the Tule Peak and Southwest Cahuilla Occurrence Complexes and reduction of off-road vehicle activity in that area.

1.5. Southwest San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within and between the occurrence complexes. Protection and management should focus on maintaining landscape connectivity between occurrence complexes in lower elevation areas surrounding Otay Mountain, San Miguel Mountain, and the Jamul Mountains. North-south landscape connectivity, as well as east-west connectivity between populations of the species in this portion of the United States is apparently achieved through the core Otay Lakes/Rancho Jamul Occurrence Complex, thus, it is critical that this connectivity be maintained. East-west landscape connectivity south of Otay Mountain and through Mexico may be maintained by the core West Otay Mountain and Marron Valley Occurrence Complexes. Protection and management of mesa areas contiguous with the Otay River Valley is also needed. Because it is possible that the core West Otay Mountain and Marron

Valley Occurrence Complexes are dependent on local populations in Mexico for persistence, the first priority should be to protect the Otay Lakes/Rancho Jamul Occurrence Complex.

1.6. Southeast San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within the recovery unit, especially south of Interstate 8.

1.7. Restore or enhance habitat patches and landscape connectivity within and between occurrence complexes. Restoration and habitat enhancement are proposed as an important component of this plan because of the pervasive alteration to Quino checkerspot butterfly habitat throughout the species' known range, as summarized above (section I.E, Current Threats). Because the Quino checkerspot butterfly was only recently listed, and there is a high level of development and outdoor recreation activity occurring throughout the species' range, much land that may be conserved is already fragmented and degraded. Even most currently conserved lands will require restoration and management to ensure Quino checkerspot butterfly recovery.

The ultimate goal of restoration efforts will be self-sustaining, functional native ecosystems similar to those that historically supported Quino checkerspot butterfly metapopulations. Restoration efforts must focus on restoring as many habitat components as possible. Effort can range from minimum, such as adding seed of larval food and adult nectar plants to enhance existing resources, to more extensive programs, such as reestablishing native plant communities in fallow agricultural fields. Site-specific ecosystem restoration planning should include data on natural vegetation community composition and physical habitat structure in the vicinity. Other habitat attributes that should be considered include soils and associated plant and animal populations (Osborne and Redak 2000). This information can often be obtained through historical notes and records, maps, photographs, and analyses of nearby relatively unaltered native communities. Data on historic conditions should be used to determine the species composition of each site whenever possible.

In areas targeted for Quino checkerspot butterfly habitat restoration, natural physical and biological attributes must be restored. Large-scale monoculture planting of *Plantago* is unlikely to be successful because other vegetation components are essential, including nectar plants and pollinators. Other habitat components, such as appropriate larval diapause and pupation sites (see Osborne and Redak 2000) are also essential. Habitat can be partially or wholly restored using methods that vary in labor intensity, disruption to existing vegetation and soils, and potential for impacts to nontarget plants and animals. Methods should be specifically chosen to meet the needs of each habitat patch (Appendix II). Research may provide additional methods and successful combinations of existing ones. Only locally collected *Plantago* seed should be used for restoration until a better understanding of *Plantago* ecology and genetics is available. Commercial supplies may not be reliable (M. Dodero and B. McMillan, pers. comm.).

1.7.1. <u>Enhance or restore landscape connectivity between isolated habitat patches in developed areas</u>. Because of the pervasive, ongoing habitat degradation caused by nonnative plant invasion, off-road vehicle activities, and other development-related impacts it is probable that habitat within all population distributions will require some level of enhancement. Restoration of habitat that has been completely destroyed by agriculture or grazing, and enhancement of dispersal areas will be necessary primarily in the Southwest Riverside and Southwest San Diego Recovery Units. Habitat patches should be connected by dispersal areas to as many other patches as possible to increase the probability of recolonization following extirpation events. Habitat networks should also be embedded in natural areas as large as possible to reduce indirect impacts of development and the need for future or ongoing restoration in occupied habitat.

Restoration of landscape connectivity in developed areas that still sustain the species will require innovative technology or perpetual management. Obstacles of particular concern are high-traffic roads. The Transportation Equity Act for the 21st Century (TEA-21) offers an opportunity for Federal agencies to facilitate reduction of highway impacts on wildlife, particularly through innovative dispersal area technology. Technology that may enhance Quino checkerspot butterfly landscape connectivity includes road overpasses coupled with deterrents to reduce mortality and channel dispersal. Similar road overpasses and deterrents have been used successfully to reduce vertebrate wildlife mortality (*e.g.* Page *et al.* 1996, Keller and Pfister 1997). A dual recreational use and habitat corridor overpass that would serve as a reasonable model for multiple species/butterfly overpasses is currently under construction in Florida (Berrios 2000). Possible deterrents include tall (3- to 10-meter [10- to 33-foot] fences or tall, dense, woody vegetation (G. Pratt, pers. comm.). Overpass linkages should require little more than nectar resources and relatively bare ground resembling sparsely vegetated habitat areas including hilltops. It may be possible to manipulate butterfly behavior and direct dispersal across overpasses (G. Pratt, C. Parmesan, and M. Singer, pers. comm.). Underpasses are less likely to improve dispersal because Quino checkerspot butterflies tend to avoid shaded areas (see section I.C.2, Adult Behavior and Resource Use).

1.7.1.1. Intensive restoration of agricultural areas and degraded habitat in the Southwest San Diego Recovery Unit will be needed within the Otay Lakes/Rancho Jamul Occurrence Complex, in Proctor Valley, and on Otay Mesa. Landscape connectivity should be enhanced across Otay Mesa through continued expansion of vernal pool restoration and other habitat restoration activities.

1.7.1.2. Intensive restoration of agricultural areas and degraded habitat in the Southwest Riverside Recovery Unit will be needed primarily in the core Skinner/Johnson Occurrence Complex, south of Lake Skinner (Johnson Ranch), and in the Warm Springs Creek/Hogbacks area.

1.7.2. <u>Remove cattle or sheep and phase in weed control where habitat is currently grazed</u>. Although grazing may suppress nonnative plant invasion, it also destroys cryptogamic crusts that naturally slow weed invasion. Cows and, in particular, sheep can trample larvae and they also eat larval host plants. Sheep grazing on Bureau of Land Management lands, as observed in Kabian Park near the Canyon Lake Occurrence complex (A. Anderson, pers. obs. 2001) should be discontinued/prohibited.

2. <u>Continue yearly reviews and monitoring as needed as part of adaptive management until there is evidence that populations associated with core occurrences are resilient</u>. Evidence of resilience is demonstrated if long-term monitoring shows that populations meet the standards summarized in Recovery Criterion 4 above. Monitoring should also be initiated subsequent to undertaking any population augmentation. One possible metapopulation viability model that could be used to determine a habitat patch occupancy threshold as described in Criterion 4 is Hanski's (1999) incidence function model, although an acceptable extirpation probability must first be identified.

Monitoring programs will be necessary to determine population trends and inform site-specific management. Butterfly conservation biologists have developed a variety of non-destructive monitoring methods for estimating population numbers and long-term density trends (Pollard 1977, Thomas and Simcox 1982, Murphy and Weiss 1988, Zonneveld 1991, Van Strien *et al.* 1997, Mattoni *et al.* 2001). These monitoring techniques do not rely on standard mark-recapture methods, but on either adult or larval web observations. Two different techniques should be adopted, one to determine habitat patch occupancy patterns within metapopulation distributions (*e.g.*, Zonneveld *et al.* in press, U.S. Fish and Wildlife Service 2002c), and another to measure changes in densities (Pollard 1977, Thomas and Simcox 1982, Murphy and Weiss 1988, Zonneveld 1991, Van Strien *et al.* 1997, Mattoni *et al.* 2001). The second technique would focus on presence/absence rather than density monitoring and maximize the area covered in a given time. Whenever possible, monitoring and research methods should be designed to simultaneously determine density and occupancy patterns (see Recovery Criteria), answer key ecological questions such as habitat suitability factors, and determine population phenology. Methods should also avoid and minimize larval mortality and habitat destruction (trampling).

3. Assess and augment lowest density populations as needed to help establish resilience. It is probable that populations associated with occurrence complexes in the Northwest Riverside Recovery Unit are no longer resilient, or may even have been extirpated. Focused surveys and monitoring should be conducted throughout the Gavilan Hills area, especially in the vicinity of the Lake Mathews population site and the Harford Springs Occurrence Complex to determine the status of Quino checkerspot butterfly occupancy in these habitat areas. These surveys should be conducted in addition to the surveys to determine resiliency described in recovery action 2 and the recovery criteria above. If no Quino checkerspot butterfly population is found after 3 consecutive years of focused surveys, augmentation should be undertaken using ranching of captive reared stock collected from the nearest known occupied habitat.

4. Establish and maintain a captive propagation program. The Quino checkerspot butterfly captive propagation program should consist of two separate, formal laboratory facilities and, if possible, include lines from representative sites throughout the species' range. Stock from each site should be kept separate until further research determines extent of historic or appropriate gene flow between them. Captive propagation is needed to ensure maintenance of locally adapted populations, to maintain local adaptations and genetic diversity, and to provide individuals from local populations for adaptive reserve management research. Stock will probably also be needed for population augmentation and reintroduction, especially in the Northwest Riverside Recovery Unit. Captive propagation should be established in a manner consistent with our policy on controlled propagation of endangered species (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2000).

Annual augmentation of captive stock with a small number of wild-captured individuals will be necessary to reduce selection for captive conditions and inbreeding depression. Collection of older females and males at the end of the adult flight season (Cushman *et al.* 1994) or when environmental conditions are not conducive to larval survival (*e.g.* drought) is recommended, and should not significantly affect metapopulation persistence. Captured females that have already deposited most of their eggs can be induced to produce more eggs than would naturally occur (G. Pratt, pers. comm.). Captive rearing facilities should also include butterfly ranches within the distribution of extant metapopulations where augmentation is deemed necessary. Butterfly ranches would consist of semi-natural areas designed and managed to produce high density populations that could disperse naturally or be manually distributed to augment extant metapopulations (B. Toon, pers. comm.). Continued support should be provided for the captive propagation facilities currently under development at Vista Murrieta High School in Riverside County. Captive rearing should also be implemented in San Diego County as generally described by Dudek and Associates (2001).

Priority 2 Recommendations:

5. Initiate and implement an outreach program to inform the public about the biology of the Quino checkerspot butterfly and the ecological significance of its decline (an indicator of ecosystem decline; Ehrlich 1992). Other important educational subjects include the ecosystem services concept (Ehrlich 1992, Field *et al.* 1999), regulatory incentives such as Safe Harbor Agreements and local cooperative partnerships, and habitat restoration techniques. It is important that outreach efforts rely on facts derived from research in order to remain unbiased and credible. Integration with biological curricula in local high schools emphasizing scientific ecological methodology and hands-on restoration activities is advised.

5.1. Develop and implement the proposed Vista Murrieta High School Project, in the Warm Springs Creek/Murrieta area. Current plans include developing a curriculum focused on the Quino checkerspot butterfly and its native ecology (Helix Environmental Planning 2000). Activities at the on-site captive propagation facility run by University of California, Riverside (see action 4 above) will be integrated into the educational outreach program. Other research activities that may be integrated with the high school curriculum are maintenance and enhancement of occupied habitat adjacent to the high school, and monitoring and possibly augmentation of populations.

5.2. Initiate a pilot program similar to that proposed for Vista Murrieta High School in the Southwest San Diego Recovery Unit, associated with the San Diego National Wildlife Refuge. An educational outreach program with Steele Canyon High School (adjacent to Refuge parcels occupied by Quino checkerspot butterflies) has been initiated, but there is no captive propagation component.

5.3. Initiate further cooperative outreach efforts with local nongovernmental organizations, educational institutions, and local museums.

5.4. Initiate an outreach program with local off-road vehicle clubs and organizations to promote mutual understanding and cooperation in the community for conservation of the Quino checkerspot butterfly and access to managed recreation areas. Emphasize common concerns, such as reduction of open space due to ongoing development and population growth. Work to encourage responsible use and create appropriate designated off-road vehicle activity areas.

6. Conduct biological research needed to refine recovery criteria and guide conservation efforts. Research will not only help to better understand the species, it is also necessary for adaptive management and forms the backbone of the recovery strategy. Some needs are simple, such as habitat mapping, but this type of fundamental information is needed before more complex adaptive management research may proceed. Research is also necessary to develop appropriate delisting criteria.

6.1. Survey areas between and around occurrence complexes to determine where there is intervening and/or additional landscape connectivity (a possible greater metapopulation distribution). Surveys should be conducted within 7 kilometers (4.4 miles) of recent butterfly observations and within all areas encompassed by recovery units because: 1) The existence of undocumented occupied habitat patches is probable; and 2) current population distributions are greatly reduced relative to historic densities and distributions, and habitat patches that support larval development will be sources of former and future population expansions needed for metapopulation resilience (see metapopulation model estimates in Harrison 1989).

6.2. Map habitat patch distributions associated with occurrence complexes. Areas that need to be mapped include: habitat patches that currently support larval development, suitable or restorable habitat patches not currently occupied by larvae, habitat areas needed for landscape connectivity, and areas where management is needed protect habitat patches from impacts of nearby development. Information gathered concurrently during surveys should include degree of nonnative species invasion and presence of local threats. Habitat mapping should be integrated with more advanced research, such as habitat suitability investigations and population modeling, as soon as possible.

6.3. Monitor ongoing habitat loss and exotic species invasion within mapped critical habitat and occurrence complexes. Because habitat loss due to development, land use changes, and off-road vehicle use is the primary threat to Quino checkerspot butterfly populations, it should be monitored. Although monitoring of butterfly populations is essential and needed to determine the status of the species, it is not enough. Butterfly population monitoring is dependent on the weather and may not be valid some years, is difficult and expensive to do, and is not easy to interpret. Butterfly population decline may also lag behind the threats that cause it. If all the recovery actions and implementation undertaken on behalf of the species do not significantly curtail habitat destruction, then there can be no recovery for the species. Landscape-scale land use changes and off-road vehicle damage can be monitored relatively easily and cheaply through aerial imagery available to us. Historic images should be examined and rate of habitat loss determined and tracked.

Exotic plant invasion is not as simple to monitor as habitat destruction, but species presence, density, and distribution sampling should at least be carried out at monitored, occupied Quino checkerspot butterfly habitat sites. Eventually invasive plant eradication and monitoring should be included in the adaptive management of occupied wildlife reserves for the Quino checkerspot butterfly and other species.

6.4. Conduct preliminary modeling of metapopulation dynamics for the Southwest Riverside and Southwest San Diego Recovery Unit occurrence complexes. These two recovery units are specified for metapopulation modeling because they contain the greatest amount of current or planned urban and suburban development, are the focus of regional Habitat

Conservation Plans that should soon provide specific Quino checkerspot butterfly management, have established and managed preserves already in place, and contain the core occurrence complexes for which we have the most historic and recent population information.

Spatially explicit theoretical models have been successfully used to guide conservation efforts in the Glanville fritillary (*Melitaea cinxia),* a close relative of the Quino checkerspot butterfly (Hanski *et al.* 1996, Wahlberg *et al.* 1996). This approach used the incidence function model to predict specific habitat patches crucial to metapopulation resilience (Wahlberg *et al.* 1996), and habitat patch structure resulting in the highest probability of metapopulation persistence (Thomas and Hanski 1997). Other types of spatially explicit models that require less detailed biological data may be more appropriate for Quino checkerspot butterfly recovery. Models should not assume that extirpation probabilities of habitat patches are independent, and should incorporate environmental correlation whenever possible (Harrison and Quinn 1989). The specific type and complexity of the model used will be dependent on available data and time constraints for recovery implementation at the time of initiation.

Because habitat quality and local climate vary from the location of one population to another, acreage needed to sustain resilient populations will also vary. Additional assessment and modeling of conditions contributing to population resilience and the restoration potential of each habitat area must be made before further refinement of metapopulation preserve design and analyses of population viability can be accomplished. Complete data needed to determine specific habitat acreage objectives for each (not yet described) metapopulation are not currently available. It is possible that modeling efforts may require extensive additional data on site-specific population and life history characteristics of the Quino checkerspot butterfly. Innovative modeling methods that could help overcome current knowledge gaps and anticipate population outbreaks include multi-valent (fuzzy) logic models based on expert knowledge (*e.g.* Salski 1992, Cao 1995), and self-organized criticality models (*e.g.* Lockwood and Lockwood 1997).

6.5. Investigate the function of hilltops as a resource for Quino checkerspot butterfly populations. It is imperative to demonstrate the nature of hilltop use by the Quino checkerspot butterfly. Answers to this question will help inform reserve design and possibly help us to understand the nature of the species' dispersal tendencies and general population dynamics.

6.6. Investigate the contribution of multiple-year diapause to metapopulation resilience. This crucial question must be answered, because it may be the key to the species' survival. The answer to this question will determine management activities such as how we conduct future monitoring, how we assess population resilience, how we manage fire regimes, and the need for population augmentation.

6.7. Investigate host plant preference and host-related larval development success on a population-by-population basis. Host plant preferences and suitability can affect metapopulation dynamics (Hanski and Singer 2001). Therefore it is important to know what effects the host plant species composition of habitat patches may have on immigration and emigration for population modeling and other management tools.

6.8. Determine the effect of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot butterfly and its host plant. It is scientifically well established that carbon dioxide levels in the atmosphere are increasing, and this increase will have profound ecological effects above and beyond associated global climate change. Although information is accumulating about the effects of elevated carbon dioxide on host plants and insect species, we know little about specific ecosystem-level effects, or possible effects on *Euphydryas editha*. Indirect effects of elevated carbon dioxide, like climate-driven range shifts, are likely to affect not only all aspects of the Quino checkerspot butterfly recovery strategy in the foreseeable future, but also the future of every other native species in southern California.

7. Document or reintroduce a population within the Lake Matthews Population Site in the Northwest Riverside Recovery Unit. The Lake Matthews population site is based on historic observations south of Lake Matthews and remaining

natural areas, primarily within the Lake-Matthews/Estelle Mountain Reserve (Figure 12). Locations likely to be suitable include the Black Rocks area, or near the new landfill to the west. Existence of a population is considered to be crucial for survival of the species, as this area was a historically stable stronghold for the species, and appears to still contain large areas of suitable habitat. If the species cannot be maintained in this area under management, we do not believe it should be downlisted.

8. Reduce firearm use and unauthorized trash dumping in habitat areas. In the South Riverside Recovery Unit, dumping and target shooting are not as destructive, but are just as pervasive in occupied butterfly habitat, as off-road vehicle activity. Dumping is also a problem in the Northwest Riverside Recovery Unit. Such activities that impact Quino checkerspot butterfly populations also reduce the visual attractiveness of natural areas and may encourage further habitat degrading activities.

9. Continue coordination with the Cahuilla Band of Indians. Discussion topics include investigating the extent of Quino checkerspot butterfly population distributions within the Cahuilla Indian Reservation and possible voluntary conservation measures. Assist in development of an environmental management plan for the Cahuilla Indian Reservation.

Priority 3 Recommendations:

10. Survey for habitat and undocumented populations in undeveloped areas outside of recovery units. There may be undocumented Quino checkerspot butterfly populations outside of recovery units that would help to meet recovery criteria, or reestablish landscape connectivity between the northern and southern recovery units.

> 10.1. Between the South Riverside/North San Diego Recovery Unit and the Southeast San Diego Recovery Unit in eastern San Diego County, particularly the west slope of the Laguna Mountains, inland hills and valleys, and the slopes of Mount Palomar. The Recovery Team believes it is possible that these areas support one or more undocumented populations of the Quino checkerspot butterfly. These areas may provide landscape connectivity between the northern and southern recovery units.

10.2. Between State Route 94 and Interstate 8 in southern San Diego County. There are several historic collections of Quino checkerspot butterflies in this area, and it may contain undocumented populations. Occupied habitat was documented at two locations just north of State Route 94 in 2001, resulting in the expansion of the final Southwest San Diego Recovery Unit compared to the draft recovery unit (U.S. Fish and Wildlife Service 2001b).

10.3. In possible future recovery units. It is possible that these areas support one or more undocumented Quino checkerspot butterfly populations (see recovery unit descriptions above). Such a population was discovered by chance in 2001, in the easternmost portion of the possible future Central San Diego Recovery Unit (Sproul and Faulkner 2001). Any viable populations discovered in these areas would be considered important to recovery of the species. It is essential that occupancy status is thoroughly investigated in these areas prior to attempts to establish any experimental populations.

10.4. Possible habitat areas in conserved areas of the Santa Ana Mountains and foothills. The large number of historic and current Quino checkerspot butterfly records in this area and surrounding areas indicate it is possible that undocumented extant populations may be found there. The possibility of extant populations in the Santa Ana Mountains is further supported by the presence of scattered areas of open-canopy vegetation and clay soils, a maximum elevation below the maximum elevation documented for Quino checkerspot butterfly populations, and newly documented species of larval host plants that have also been collected in this area.

11. Survey areas not otherwise recommended for surveys that fall within the latest recommended survey area map. There are a number of areas where Quino checkerspot butterfly population distributions, or isolated local populations, may fall outside of areas specifically named above. These areas fall within the recommended survey areas on the latest Quino checkerspot butterfly survey protocol map (U.S. Fish and Wildlife Service 2002c). These areas, although not currently considered to be important for recovery, could still contain occupied habitat. Surveys are important to avoid possible unauthorized take of the

butterfly under section 9 of the Endangered Species Act. Occupied habitat discovered by surveys could also be determined to be important to recovery at a later date, and would be considered if downlisting criteria are revised or delisting criteria are developed.

12. Enter into dialogue with Baja California, Mexico nongovernmental organizations and local governments. Discussion topics include beginning surveys to determine the extent of the West Otay Mountain, Marron Valley, and Jacumba population distributions across the border, and protection and management of landscape connectivity south of Otay Mountain.

D. Preliminary Recommendations for Possible Future Recovery Units

Possible Future Central San Diego Recovery Unit:

- Assess current information on population status in this area (including data from further habitat and butterfly surveys) and determine appropriate recovery unit boundaries, including if it should be two Recovery Units or one, and if it should be two, which unit should contain the San Vicente Reservoir Occurrence Complex.
- Based on analysis of habitat and determination of recovery unit boundaries, develop a draft addendum to the final recovery plan describing one or two new recovery units and an edited step-down narrative and implementation schedule. Submit draft addendum for Recovery Team review and publish for public review and comment.
- Determine the extent of the population distributions associated with the two recently documented occurrence complexes.
- Maintain and restore landscape connectivity between the eastern occupied habitat areas and the western mesa habitat areas.
- Map distribution and assess suitability of habitat.
- Restore vernal pools and other habitat where needed.
- Survey for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot butterfly density at monitored reference sites. Follow monitoring recommendations in San Vicente Reservoir and Alpine Occurrence Complexes.
- Maintain connectivity with eastern undeveloped areas to reduce indirect impacts of development.

- Determine habitat distribution and landscape connectivity potential in undeveloped areas between the recovery unit and the Laguna Mountains.
- Reintroduce an experimental population somewhere in th western coastal mesa habitat areas.
- Determine what military activities are most likely to affect Quino checkerspot butterfly populations and how best to minimize conflict between population management and essential ongoing military training.

<u>Possible Future Northwest San Diego Recovery Unit</u>:

- Map distribution and suitability of habitat.
- Conduct focused surveys for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot butterfly density in Riverside County reference populations.
- Determine extent of imported fire ant (*Solenopsis invicta*) invasion and possible conflicts with Quino checkerspot butterfly occupancy.
- Determine extent of landscape connectivity with possible future North Orange Recovery Unit and the eastern slope of the Santa Ana Mountains.
- Determine what military activities are most likely to affect Quino checkerspot butterfly populations and how best to minimize conflict between population management and essential ongoing military training.

<u>Possible Future North Orange Recovery Unit:</u>

- Develop integrated comprehensive Quino checkerspot butterfly management plan for the Fremont Conservation area and adjacent Cleveland National Forest lands within the survey area (U.S. Fish and Wildlife Service 2002c).
- Remove cattle grazing from Black Star Canyon and phase in weed control.
- Restore habitat around Irvine Lake and reintroduce the Quino checkerspot butterflies.
- Determine extent, suitability, and landscape connectivity of habitat along the western slope of the Santa Ana Mountains to the possible future Northwest San Diego Recovery Unit.
- Conduct focused surveys for butterflies in the highest-quality habitat sites during years of confirmed high Quino checkerspot butterfly density in monitored reference sites.

- Determine extent of imported fire ant (*Solenopsis invicta*) invasion and possible conflicts with Quino checkerspot butterfly occupancy.

III. IMPLEMENTATION SCHEDULE

The schedule that follows is a summary of actions and estimated costs for the Quino checkerspot butterfly recovery program. It is a guide to meet the objectives of the recovery plan as elaborated in Part II, Step-Down Narrative section. This schedule indicates recovery action priorities, action numbers, action descriptions, duration of actions, responsible agencies, and estimated costs. These actions, when accomplished, should achieve the recovery objectives. The estimated costs for some actions remain to be determined, and funding for some actions will come from sources not wholly attributable to the Quino checkerspot butterfly. Our staff salary is not included in cost estimates. Responsible party listings are based primarily on recent (1986 and later) Quino checkerspot butterfly observation site land ownership data, jurisdictional authority, and responsibility for road and highway construction. Cost is not separated by responsible agency; distribution of costs among agencies is to be determined. Listing a party as responsible does not necessarily mean that responsibilities are increased above and beyond prior responsibilities or costs, nor are responsibilities necessarily obligate. The list of responsible parties is not exhaustive.

Please note that costs in the implementation schedule are *estimates* based on the best information available to us, and do not constitute a comprehensive economic analysis of the resources needed to accomplish recovery tasks for the Quino checkerspot butterfly. Actual task costs may be greater or lesser than the estimates provided below.

<u>Definitions and Abbreviations Used in the Implementation Schedule</u>:

Priorities in column one were assigned as follows:
1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
2 - An action that must be taken to prevent a significant decline in species' population, habitat quality, or some other significant negative impact short of extinction.
3 - All other actions necessary to meet the recovery objectives.

Key to Acronyms used in the Implementation Schedule:

ABDSP	Anza Borrego Desert State Park
BCNG	Baja California Norte Government
BLM	Bureau of Land Management
BP	Border Patrol
Caltrans	California Department of Transportation
CBI	Cahuilla Band of Indians
CCL	City of Canyon Lake
CCV	City of Chula Vista
CDF	California Department of Forestry
CDPR	California Department of Parks and Recreation
CLE	City of Lake Elsinore
CM	City of Murrietta
CNF	Cleveland National Forest
CP	City of Perris
CPW	City of Poway
CSD	City of San Diego
CT	City of Temecula
IC	Imperial County
LMEMRMC	Lake Mathews/Estelle Mountain Reserve Management Committee
MCASM	Marine Corps Air Station, Miramar
MCBCP	Marine Corps Base, Camp Pendleton
MNG	Mexican National Government
MVSD	Murrieta Valley Unified School District
NGO	Nongovernmental Organizations
OC	Orange County
PP	Project proponents (unspecified)
PU	Pepperdine University
RC	Riverside County
SBNF	San Bernardino National Forest
SDC	San Diego County
SDNHM	San Diego Natural History Museum
SDSU	San Diego State University
SDZ	San Diego Zoo
TBD	To be determined
TNC	The Nature Conservancy
UCI	University of California, Irvine

UCR	University of California, Riverside (in some cases authorized staff)
UCSD	University of California, San Diego
USD	University of San Diego
USAW Inc.	USA Waste Incorporated
USFWS	U.S. Fish and Wildlife Service
UTA	University of Texas, Austin (authorized staff)
WRMSRMC	Western Riverside County Multiple Species Reserve Management Committee

*	Lead responsible agency
†	Costs of land acquisition and management for the six recovery units are a major component of the cost of recovery, but cannot be reasonably estimated. Total estimated acreage requiring acquisition is approximately 55,000 hectares (135,000 acres), of which approximately 40,000 hectares (100,000 acres) are privately owned. Land acquisition costs vary substantially among and within recovery units, ranging roughly from $4,000 to $35,000 per acre, and may change over time in response to zoning changes or the real estate market. Costs of land protection may be reduced through participation in land swaps, habitat conservation plans, conservation easements, management agreements, or other conservation tools. Much of the Quino checkerspot butterfly habitat to be protected under the San Diego County MSCP and Western Riverside County MSHCP will also serve to conserve other cooccurring endangered species and will be funded independently of Quino checkerspot conservation, so the cost of habitat protection is only partially attributable to the Quino checkerspot butterfly.

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	1.1.	Northwest Riverside Recovery Unit: Protect and manage as much as possible of the habitat that is part of the known historic Gavilan Hills/Lake Mathews population distribution and associated with the Canyon Lake Occurrence Complex, in a configuration designed to support a resilient metapopulation. Develop a Quino checkerspot butterfly management plan for the Lake Mathews/Estelle Mountain Preserve.	Ongoing	USFWS*, LMRMC, RC, BLM, USAW Inc., CLE, CCL, CP, NGOs	TBD†	TBD†	TBD†	TBD†	TBD†	TBD†

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN

Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's) FY 03	FY 04	FY 05	FY 06	FY 07
1	1.2.	<u>Southwest Riverside Recovery Unit</u>: Protect and manage as much of the remaining habitat as possible that is part of the known population distributions, in a configuration designed to support resilient metapopulations. Develop a Quino checkerspot butterfly management plan for Southwest Riverside County Multiple Species Reserve (Lake Skinner) and an additional reserve in the vicinity of Warm Springs Creek. Preserve as much natural area as possible in the French Valley between occurrence complexes.	Ongoing	USFWS*, CDFG, RC, CT, CM, UCR, WRMSRMC, NGOs	TBD†	TBD†	TBD†	TBD†	TBD†	TBD†
1	1.3.	<u>South Riverside Recovery Unit</u>: Protect and manage as much as possible of the remaining habitat within and between the occurrence complexes, in a configuration designed to support resilient metapopulations.	Ongoing	USFWS*, RC, BLM, CNF, NGOs	TBD†	TBD†	TBD†	TBD†	TBD†	TBD†

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN

Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
1	1.4.	South Riverside/North San Diego Recovery Unit: Protect and manage as much as possible of the remaining habitat within and between the occurrence complexes, in a configuration designed to support resilient metapopulations.	Ongoing	USFWS*, BLM, RC, SDC, PU, CBI, CNF, SBNF, NGOs	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]
1	1.5.	Southwest San Diego Recovery Unit: Protect and manage as much as possible of the remaining habitat within and between the occurrence complexes, in a configuration designed to support resilient metapopulations. Specifically, surrounding Otay Mountain, east through Tecate Peak, and north through Proctor Valley.	Ongoing	USFWS*, BLM, SDC, CCV, CDFG, CDF, CSD, NGOs, BP	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]
1	1.6.	Southeast San Diego Recovery Unit: Protect and manage as much as possible of the remaining undeveloped suitable and restorable habitat patches and dispersal areas within the recovery unit, especially south of Interstate 8.	Ongoing	USFWS*, SDC, ABSP, BLM, NGOs, BP	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]	TBD[†]

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN

Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's) FY 03	FY 04	FY 05	FY 06	FY 07
1	1.7.1.1.	Intensive restoration of agricultural and grazed areas or otherwise degraded habitat in the Southwest San Diego Recovery Unit.	13	USFWS*, SDC, CSD, CCV, CDFG	67,600	20	30	25,000	21,000	8,000
1	1.7.1.2.	Intensive restoration of agricultural areas and degraded habitat in the Southwest Riverside Recovery Unit	15	USFWS*, RC, CT, CM	71,000	0	20	40	29,000	23,000
1	1.7.2.	Remove cattle or sheep and phase in weed control where habitat is currently grazed.	5	USFWS*, BLM, SBNF, CSD	28	8	8	6	4	2
1	2.	Continue yearly reviews, monitoring as needed as part of adaptive management until there is evidence that populations associated with core occurrence complexes are resilient.	16	USFWS*, CDFG, SDC, RC	192	12	12	12	12	12
1	3.	Assess and augment lowest density populations as needed to help establish resilience.	TBD	USFWS*, CDFG, SDC, RC	15+	5	5	5	TBD	TBD
1	4.	Establish and maintain a captive propagation program.	Ongoing	USFWS*, MVSD UCR, Caltrans, UTA	490	40	30	30	30	30

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
2	5.1.	Develop and implement the proposed Vista Murrieta High School educational outreach project (Helix 2000), in the Warm Springs Creek/Murrieta area.	Ongoing	USFWS*, UCR, MVSD	2	1	1			
1052	5.2.	Initiate an educational outreach similar to that proposed for Vista Murrieta High School in the Southwest San Diego Recovery Unit, associated with the San Diego National Wildlife Refuge Complex.	Ongoing	USFWS*, NGOs	48	3	3	3	3	3
2	5.3.	Initiate further cooperative outreach efforts with local nongovernmental organizations, educational institutions, and local museums.	Ongoing	USFWS*, NGOs, SDNHM, SDSU, USD, SDSU, UCR, UCSD, UCI, SDZ	32	2	2	2	2	2
2	5.4.	Initiate a outreach program with local off-road vehicle clubs and organizations to promote mutual understanding and cooperation in furthering conservation of the butterfly.	6	USFWS*, RC, BLM, NGOs	9	1	2	3	1	1
2	6.1.	Survey areas between and around occurrence complexes to determine where there is intervening and/or additional landscape connectivity.	6	USFWS*, RC, SDC, BLM, SBNF, CNF, PP	140	25	35	35	25	15

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
2	6.2.	Map habitat patch distributions associated with occurrence complexes.	10	USFWS*, SDC, RC, CDFG	94	6	8	10	10	10
2	6.3.	Monitor ongoing habitat loss and exotic species invasion within mapped critical habitat and occurrence complexes.	Ongoing	USFWS*, SDC, RC, CDFG	168	12	12	12	12	10
2	6.4.	Conduct preliminary modeling of metapopulation dynamics for the Southwest Riverside and Southwest San Diego Recovery Unit occurrence complexes.	2	USFWS*, SDC, RC	22	0	10	12	0	0
2	6.5	Investigate the function of hilltops as a resource for Quino checkerspot butterfly populations.	4	USFWS*, SDC, RC	32	0	8	8	8	8
2	6.6.	Investigate the contribution of multiple-year diapause to metapopulation resilience.	8	USFWS*, SDC, RC	48	0	6	6	6	6
2	6.7.	Investigate host plant preference and host related larval development success on a population-by-population basis.	4	USFWS*	32	0	8	8	8	8
2	6.8.	Determine the effect of elevated atmospheric carbon dioxide and nitrogen fertilization on the Quino checkerspot butterfly and its host plant.	10	USFWS*	150	15	15	15	15	15

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
2	7.	Document or reintroduce a population within the Lake Matthews Population Site in the Northwest Riverside Recovery Unit.	TBD	USFWS*, RC, LMEMRMC	12+	4	4	4	TBD	TBD
2	8.	Reduce firearm use and unauthorized trash dumping in habitat areas.	6	USFWS*, BLM, RC, SDC, NGOs	200	50	50	40	30	20
2	9.	Continue dialogue with the Cahuilla Band of Indians.	Ongoing	USFWS*, CBI	19	2	2	2	1	1
3	10.1.	Survey for habitat and undocumented populations between the South Riverside/North San Diego Recovery Unit and the Southeast San Diego Recovery Unit in eastern San Diego County.	6	USFWS*, SDC, CNF, SDSU, PP	120	20	30	30	20	10
3	10.2.	Survey for habitat and undocumented populations between State Route 94 and Interstate 8 in southern San Diego County.	6	USFWS*, SDC, CNF, CDFG, BLM?, PP	120	20	30	30	20	10
3	10.3.	Survey for habitat and undocumented populations in possible future recovery units.	6	USFWS*, SDC, OC, USMCCP, USMCASM, CSD, PP	140	25	35	35	25	15

IMPLEMENTATION SCHEDULE FOR THE QUINO CHECKERSPOT BUTTERFLY RECOVERY PLAN										
Priority #	Task #	Task Description	Estimated Task Duration (Years)	Primary Responsible Parties	Estimated Cost over 16 years ($1,000's)	Cost ($1,000's)				
						FY 03	FY 04	FY 05	FY 06	FY 07
3	10.4.	Survey for habitat and undocumented populations in the Santa Ana Mountains and foothills.	6	USFWS*, OC, RC, CLE, TNC, SDSU	120	20	30	30	20	10
3	11.	Survey areas not otherwise recommended for surveys that fall within the latest recommended survey area map.	Ongoing	USFWS*, SDC, RC, OC, USMCCP, USMCASM, IC, CSD, CCV, CPW, CT, CM, CLE, CCL, SBNF, CNF, ABDSP, BLM, CDFG, PP	165	20	30	30	20	10
3	12.	Enter into dialogue with Baja California, Mexico, nongovernmental organizations and local governments.	Ongoing	USFWS*, MG, BCNG, NGOs	19	2	2	2	1	1

Total Estimated Cost of Recovery Through Fiscal Year 2018: $140,990,000 + additional costs that cannot be determined at this time.

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Bauer, D. University of Colorado - Boulder. Boulder, Colorado.
Chiariello, N. Stanford University. Stanford, California.
Couffer, M. Bonterra Consulting. Costa Mesa, California.
Dodero, M. RECON, Inc. San Diego, California.
Faulkner, D. San Diego Natural History Museum. San Diego, California.
Keeley, J. U.S. Geological Survey. Riverside, California.
McMillan, B. Carlsbad Fish and Wildlife Office, U.S. Fish and Wildlife Service. Carlsbad, California.
Murphy, D. University of Nevada - Reno. Reno, Nevada.
Osborne, K. Independent Lepidopterist. Riverside, California.
Parmesan, C. University of Texas. Austin, Texas.
Pratt, G. University of California - Riverside. Riverside, California.
Reed, S. Teracore Resource Management. Temecula, California.
Sanders, A. University of California - Riverside. Riverside, California.
Singer, M. University of Texas. Austin, Texas.
Stanton, E. Center for Natural Lands Management, Sun City, California.
Toon, B. San Diego Zoological Society. San Diego, California.
VanHoffman, M. San Diego National Wildlife Refuge, U.S. Fish and Wildlife Service. San Diego, California.
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APPENDIX I

Quino Checkerspot Butterfly Life Cycle Diagram

Prepared by Dr. Gordon Pratt.
Photographs by Greg Ballmer.
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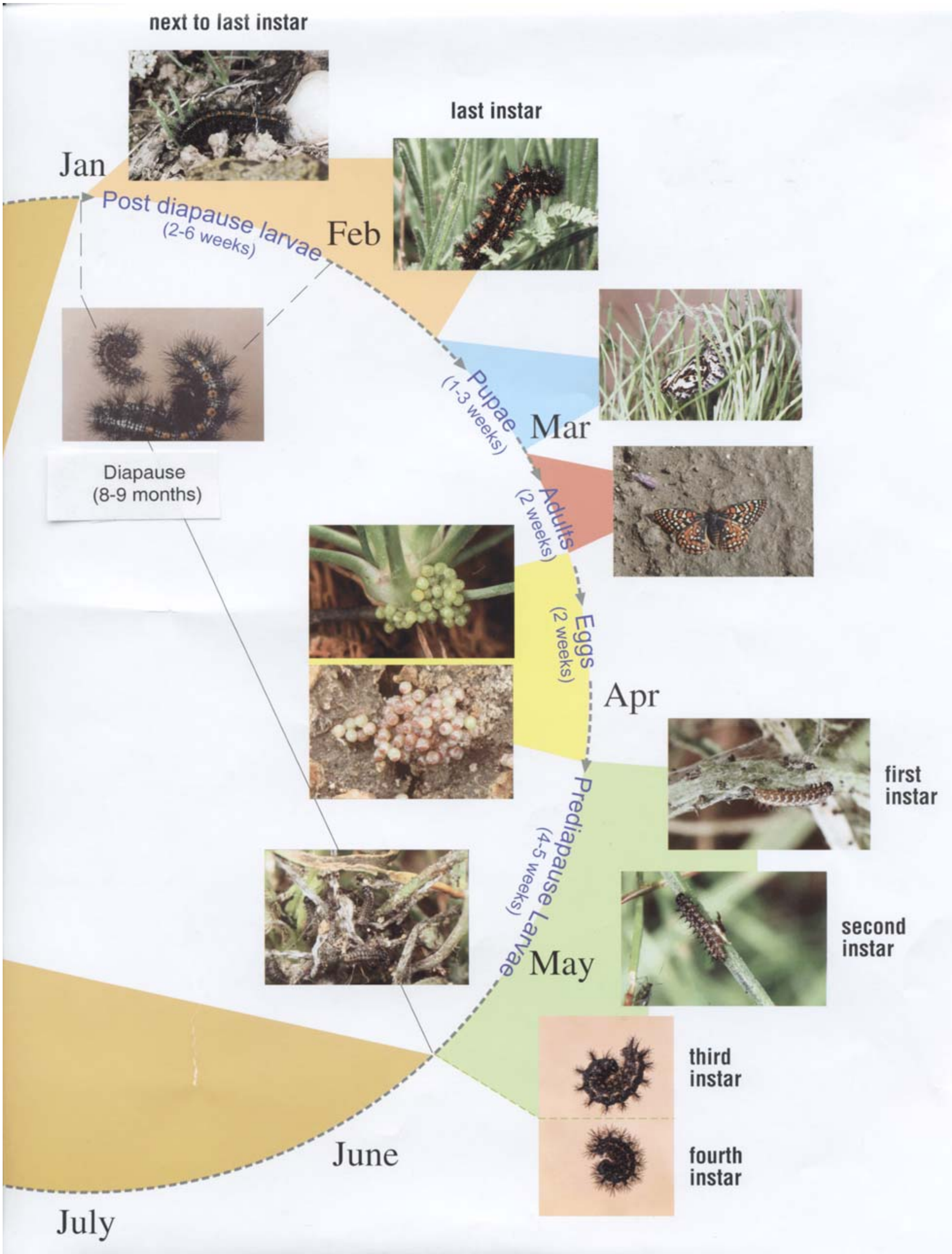
This diagram depicts a typical Quino checkerspot butterfly life cycle. There is overlap in the life stages due to population variability. Seasonal timing is also variable, depending on annual fluctuations in climate (particularly precipitation). Photographs are not to scale.


next to last instar
last instar
Jan
Post diapause larvae
(2-6 weeks)
Feb
Diapause
(8-9 months)
Pupae
(1-3 weeks)
Mar
Adults
(2 weeks)
Eggs
(2 weeks)
Apr
first instar
Prediapause Larvae
(4-5 weeks)
second instar
May
third instar
fourth instar
June
July

APPENDIX II

Habitat Restoration Methods

Prepared by Mark Dodero, RECON, Inc.

The conservation and recovery of the Quino checkerspot butterfly requires not only the preservation of currently suitable, but also the restoration of degraded, habitat for re-establishment of fully functioning metapopulations. Stabilization and re-establishment of the species (within even a small fraction of its historic range) will require long-term restoration and management efforts, possibly in perpetuity. This article discusses a variety of methods involved in, and issues related to, restoration, including: restoring habitat occupied by larvae; removing and controlling nonnative (or native) plant species; preparing the site; selecting native plant species; collecting native plant seed; restoring cryptogamic crusts; using salvaged materials; monitoring and maintaining the restored habitat, implementing adaptive management techniques; and the potential costs associated with these activities.

Restoring Habitat Occupied by Larvae

A primary goal of most habitat restoration programs is to connect and enlarge suitable habitat patches by removing nonnative plants in adjacent areas. Special precautions need to be taken if the site is occupied by the Quino checkerspot butterfly or other listed species. Usually, workers should begin removing nonnative plants at the center of occupied habitat patches and work outward, concentrically enlarging and connecting the habitat patches. This work will require on-site monitoring by a biologist familiar with the distribution of Quino checkerspot butterfly and other listed or sensitive plant and animal species.

Nonnative plant removal strategies should be site-specific to take advantage of habitat breaks such as those created by large shrub patches, canyon edges, rock outcrops, or roads. These breaks can serve as buffer zones from adjacent areas that are dominated by nonnative plants. Designing the complete restoration of metapopulation habitat patch networks by taking advantage of existing breaks will enable managers to use nonnative plant removal funds most efficiently. Initially concentrating efforts in occupied habitat patches will improve the habitat quality until resources are available to restore larger areas. After nonnative plant removal, populations of native annuals may be enhanced or re-established in and between existing habitat patches by hand seeding.

Restoring Occupied Habitat Dominated by Nonnative Plants when Native Species are Still Present

Native plant communities invaded by nonnative species can be weeded using different methods, depending on the site conditions and the presence of sensitive resources. Some habitat patches will require only spot herbicide spraying, and possibly hand removal of individual nonnative plants. Other methods can also be used, although some nonnative plant control methods, such as the use of pre-emergent or other herbicides, may not be appropriate in Quino checkerspot butterfly habitat. Site-specific nonnative plant control strategies will be needed. Timing of nonnative plant control efforts is crucial to success. If nonnative plants are not killed prior to seed set, then removal effort and cost will remain high over time. Another crucial component of the nonnative plant removal method described below is that workers must be trained to distinguish between native and nonnative plants for restoration to be successful.

This method of restoring native plant communities described below, involving removal of dead plant thatch using hand tools and "weed eaters," and return visits for spraying with glyphosate (a selective herbicide), appears to be successful on sites in central and southern San Diego County. Thick thatch can prevent native species from germinating and/or competing successfully for light and space with nonnatives.

If nonnative plants are present at moderate to high levels in areas that still have significant numbers of native species present, the following de-thatching technique can be used to restore or enhance these sites. De-thatching should be used in areas that have a buildup of organic matter on the soil surface, such as dead mustard or annual grasses.

De-thatch and Repeat Spray Method (in order):

- Cut thatch and dead nonnative plants with "weedeaters." This cutting can be done during the summer or early fall.
- Rake up and collect nonnative plant thatch.

- Remove thatch from site and dispose of it in dumpsters, a landfill, or an area where it can be composted nearby to reduce disposal costs.
- Return to site and spray Roundup® (or more selective herbicide) on nonnative plant seedlings after sufficient rains have fallen in winter and spring.
- Repeat spraying as necessary to prevent seed set. Other options include the use of pre-emergent herbicide prior to the first significant rain.
- Repeat spraying as necessary to maintain nonnative plant density to a low level. If nonnative plants are controlled each season prior to flowering and setting seed, the level of effort required should decrease.

The nonnative plant removal process must be carefully monitored because frequently, as the dominant nonnative plant species are removed, other nonnative plant species multiply rapidly and replace the formerly dominant nonnative species. Repeated nonnative plant removal visits are necessary, and adaptive management strategies must quickly address control of newly dominant nonnative species. Frequent site visits are necessary during the growing season to assess nonnative plant removal efforts and to determine whether changes are needed in the strategy being used or the intensity of nonnative plant removal efforts. This type of nonnative plant removal effort requires control efforts prior to flowering and seed development. As nonnative plants are controlled over the first few years, natives will return to dominance. Removal of nonnative plants by hand may be required around small populations of herbaceous natives. Expansion of herbaceous annuals, including *Lasthenia* (goldfields) and *Plantago* (plantain), which may be locally rare because of nonnative plant competition, may require population augmentation and careful hand removal of nonnatives.

Restoring Habitat not Occupied by Larvae, Completely Dominated by Nonnative Plants

If nonnative plants dominate a heavily disturbed restoration site completely (few or no native plant species occur) and the thatch is well incorporated into the soil, it can be more cost-effective to use heavy equipment over a large area to remove thatch and nonnative plant seed banks. Soil scraping probably works best if there are existing patches of native habitat adjacent to the site to allow immigration of native flora and fauna. This type of nonnative plant control technique can be used for fallow agricultural fields. Bulldozers or other mechanical scraping equipment can be used to remove the top organic thatch-covered layers of soil (a few inches or more if necessary. The goal of scraping is to reach the upper sub-soil, which does not have organic buildup, unnaturally high nutrient levels, or nonnative plant seeds. Soil can be removed from the site and used as fill. If the soil cannot be removed from the site, it should be deeply buried to reduce the likelihood of nonnative plant seed dispersal.

After scraping away the thatch and the top organic layers of soil, salvaged topsoil with a minimal nonnative seedbank can be obtained from other areas and can be spread over the restoration site. This procedure will provide the site with soil microorganisms, fungi, invertebrates, and seeds of native species. After scraping, winter rains will cause nonnative weed seeds to germinate, requiring nonnative plant control efforts. Repeat spraying visits can be used as described above and can be very effective, especially if used in conjunction with high-quality salvaged topsoil.

Heavily disturbed habitats that have not been used for agriculture may contain native plant species such as bunchgrasses and bulbs. To evaluate what methods should be used to remove weed thatch from a site, it is important to visit the site during the spring prior to scraping to determine whether native bulbs or other species are present. These native plants might be missed during a summer visit. This problem should not exist for agricultural fields, only for heavily disturbed areas that were not farmed and may still have natives. If small numbers of native plants are present, they can be avoided or salvaged prior to scraping and then replanted or used for propagation. If no undisturbed areas exist adjacent to the site, or if significant numbers of native species are present, the area should be de-thatched with hand tools as described above to reduce the impacts of weed removal on the soil fauna. It is important that nonnative plant control methods minimize impacts to the native invertebrate fauna.

Native Plants for Habitat Restoration and Enhancement

Seeds of native plant species used in each restoration project should be locally collected whenever possible. If a plant species was historically present in an area but can no longer be found, it should be reintroduced from the locality nearest the restoration site. Local collection of seed is especially important with regard to Quino checkerspot butterfly host and nectar plants, but should be done for as many other species as possible. Locally adapted plants are better competitors than plants introduced from a different climate zone. Seed collection should generally occur within 8 kilometers (5 miles) of a proposed restoration or enhancement site. If collecting within this distance is not possible, it is best to collect seeds as close as possible within the same general climate zone. General climate zones outlined in the Sunset Western Garden Book (Sunset Publishing Corporation 1995) can be used as a guide. Reciprocal transplant experiments have shown that plants of genotypes that are not locally adapted are inferior competitors when they are moved to a different climate zone. In addition, introducing plants that are not locally adapted can be detrimental to local herbivorous insects.

Much of the plant material required for restoration of Quino checkerspot butterfly habitat will include annuals and bulbs. Many of these species will be difficult to collect from the wild in sufficient quantity to seed the restored areas. Collecting from the wild must be limited so it will not adversely affect source plant populations. To ensure that adequate seed is available, seed bulking (growing seed in cultivation to increase the amount of seeds) of annuals, including *Plantago* and nectar plants, will be necessary. This seed bulking should be done at growing areas that can provide reproductive isolation from related plants from different regions. Plants from different source regions should not be allowed to hybridize at a common growing facility, but locally adapted genotypes for plants should be maintained as much as possible. It can take 3 years to grow bulbs from seed to a size large enough to plant and still have high survivorship when they are planted out. Therefore, restoration of diverse grassland sites, for instance, can require several years of planting.

Enhancement of Pollinator Populations

Providing adequate habitat for pollinator assemblages is crucial to the success of any Quino checkerspot butterfly restoration project. Pollinators are required to ensure that Quino checkerspot butterfly nectar plants have high seed set and persist over the long term. In arid environments, many potential pollinators, including native bee species, require open ground for nesting (Buchmann and Nabhan 1996). Extensive nonnative plant cover continues to invade and dominate current and historic Quino checkerspot butterfly habitat in southern California, resulting in a loss of open ground suitable for ground nesting pollinators. By reducing available nesting sites, the nonnative plant growth is causing a decline in pollinator numbers and diversity, with negative implications for the entire ecosystem.

As well as reducing the extent of open areas required for ground nesting pollinators, competitive interactions between nonnative and native plant species, including *Plantago erecta* (dwarf plantain), *Lasthenia* sp.(goldfields), bulbs, and rare plants are causing declines in the biological diversity of natural communities. In order to support a diverse assemblage of potential pollinators and native plant species, areas of open ground within associated native plant communities must be restored to support ground nesting bees and other invertebrates. The goal of having open ground for pollinators is compatible with Quino checkerspot butterfly restoration efforts because Quino checkerspot butterfly larval food and adult nectar plants require open ground for successful reproduction and long-term persistence.

Restoration plantings should include nectar-producing plant species with overlapping flowering periods that extend throughout the typical southern California growing season. Although there are exceptions, in general many of the nectar producing plants of arid Southwest environments (including coastal sage, grasslands and vernal pools habitats in Southern California) are visited by generalist pollinating insects (Buchmann and Nabhan 1996). Generalist pollinators visit more than one plant species for their nectar and pollen. To support pollinator assemblages throughout the flowering season, re-establishment and enhancement of nectar-producing plant populations may be required as part of restoration efforts. Even though a primary goal of Quino checkerspot butterfly habitat restoration is to enhance nectar resources specifically used by Quino checkerspot butterflies, generalist pollinators may require additional temporally overlapping nectar resources to support their populations throughout the year. At a minimum, restoration should include several nectar-producing plant species that in combination flower from early spring through late summer, as seen in relatively undisturbed natural ecosystems in southern California.

For example, species that provide good nectar resources include *Lasthenia* sp. (goldfields) and *Layia* sp. (tidy tips), which flower in early spring; *Grindelia* sp. (gumplant), which flowers later but overlaps with goldfields; and other herbs such as *Hemizonia* sp. (tarplants) and shrubby species such as *Isocoma* sp. (goldenbush), which flower in late spring and during the summer. The re-establishment of these or other appropriate species on a restoration project site will provide a continuous nectar source to keep local pollinator assemblages supplied with resources until the fall, when many pollinating insects become dormant or enter another phase of their life cycle. Each region will has its own set of nectar-producing plants, and restoration projects should be designed on a site-specific basis with the goal of supporting viable populations of potential pollinators.

Restoration of Cryptogamic Crusts

Although the science of restoring cryptogamic crusts is still in its infancy and the regeneration process requires a long time for full development, there are known techniques to promote conditions that are appropriate for the growth of these biotic crusts. Observations of older disturbed habitat in San Diego County and elsewhere indicate that soil crusts can recover following a disturbance. The process takes many years and proceeds more slowly in xeric environments than in more mesic sites. Redevelopment of biotic crust on disturbed sites is likely to produce more species diversity when intact soil crusts exist adjacent to the disturbed area. Moisture and soil conditions are the most important factors to consider when promoting crust growth.

Belnap *et al.* (1999) listed five factors that increase moisture on the soil surface and therefore promote crust development: 1) closely spaced plants; 2) flat areas (depositional surfaces rather than erosional surfaces); 3) limited surface rocks, roots, or light plant litter to slow water and wind; 4) soils with inherently high stability (silt/clay>sandy>shrink-swell clay); and 5) stable microhabitats (under shrubs, away from small washes). As soil stability increases and human-related disturbances decrease, rich communities of cyanobacteria, mosses, and lichens become more widespread, covering all surfaces not occupied by vascular plants and rocks.

Recent attempts have been made to reintroduce soil crust organisms to restoration sites on Otay Mesa, in San Diego County. Crust organisms such as *Selaginella cinerascens* (ashy spike-moss) and other associated crust flora such as liverworts, mosses, fungi, and lichens have been salvaged from recently developed areas and planted into restoration sites. One way to translocate spike-moss is to cut it into squares about the size of a greenhouse flat using hand tools and place the squares into the flats for transport or temporary storage. When soils at the restoration site are moist, the spike-moss can be planted into shallow holes excavated in the shape of the flat. The spike-moss is planted in the hole so that it is flush with or slightly below the surrounding soil surface. This placement reduces the chance that erosion will break apart the crust. New crust organisms have been grown on a small scale by placing salvaged native topsoil in greenhouse flats and then keeping them continually moist in a shaded growing structure.

These small-scale biotic crust restoration trials have produced actively growing liverworts, mosses, and ashy spike-moss. Large-scale production could be used to grow many units of crust, which can be planted at the restoration sites after nonnative plants are removed or under control. Salvaged brush is also being used to promote the growth of crusts by placing branches on open ground after the site is well weeded. The branches alter the soil moisture conditions by reducing evaporation. Mosses and algae have been observed growing under the branches within 1 year after the branches have been put in place. Future efforts to promote crust development will include salvaging crust from development impact sites during the summer dry season and then using the powdered dry soils to sprinkle over stable soil areas that are lightly covered with branches.

Using Salvaged Materials

Topsoil

Salvaged topsoil can also be used from nearby construction sites to enhance the restoration areas, including bringing in native plant propagules and soil fauna. Topsoil should only be salvaged from areas that are not infested with nonnative plants. Salvaged topsoil must be placed at the recipient site as soon as possible to maintain the maximum diversity of seeds and other soil organisms. The greatest chance of success in using salvaged topsoil is to collect soil in the summer or early fall dry period. If soils are wet when moved and spread greater damage to the native seed bank and soil organisms will occur than if the soil is dry and organisms are dormant. Soil should be stockpiled only if absolutely necessary because the longer the soil is stored the greater the loss of seeds and soil fauna. If soil must be stockpiled, it should be kept dry. The depth of piles in storage should not exceed 90 centimeters (3 feet) to avoid composting effects, and a depth of 30 to 60 centimeters (1 to 2 feet) is preferable for maintaining seed banks. The topsoil translocation site should be prepared prior to topsoil delivery.

Brush and Rocks

The following techniques can be used to increase the structural diversity of the restoration area to provide cover sites for invertebrates, including Quino checkerspot butterflies. Brush piles, scattered sticks, branches, and rock cobbles can be brought to the restoration site to increase the available cover for many animals, and will provide potential diapause and pupation sites for Quino checkerspot butterflies. Brush can be obtained from nearby construction sites, either from brush habitat affected by development or from brush management activities adjacent to structures. Because brush material is considered a waste product and has to be chipped and removed to a landfill, most construction supervisors will truck the material to your restoration site if it is near the construction area. This approach can save the developer costs associated with trucking the material to a landfill. Creative partnerships with developers can result in increased structural diversity of your restoration site.

Placement of decaying wood and brush in the restoration site can provide immediate cover for many animals, including larvae and pupae of Quino checkerspot butterflies. By bringing in brush and rocks (if appropriate to the specific site) it is possible to "jump start" restoration by providing cover that would take many years to develop or accumulate otherwise. The use of one or two restoration enhancement techniques, such as placement of brush and rocks, can benefit multiple species when done using an integrated ecosystem approach. For example, brush piles and sticks, which should benefit the Quino checkerspot butterfly, can also provide food for termites that are the primary food source for orange-throated whiptail lizards (*Cnemidophorus hyperythrus*), a sensitive species likely to be included in a multiple species conservation program. The use of structural enhancement techniques that benefit multiple species will increase the chance of successful implementation of restoration for multiple species habitat conservation plans.

Native Plants

Many species of native plants can be salvaged from construction impact areas prior to development. Translocation of native shrubs and herbaceous perennials is most successful under cool moist weather conditions after rains have started native plant growth and just prior to anticipated rainfall. Bulbs can be excavated from the soil as they become dormant in late spring after flowering has ceased. Bulbs can be stored until the fall when they can be planted after significant rains.

Restoration Costs

Habitat restoration costs vary per site, depending on site preparation costs, maintenance and monitoring requirements and the number of sensitive species needed to be present reintroduced and managed for to meet specific project standards. For Quino checkerspot butterfly restoration, maintenance of the site should last a minimum of 5 years, probably longer for converted agricultural fields, with a monitoring period of 10 years before determination of project success for mitigation purposes. Many of the degraded habitats will require at least 3 years of restoration work before reintroduction of the Quino checkerspot butterfly can be initiated. In sites that have been completely reconstructed, such as former agricultural fields, at least 15 years will be required to determine if efforts to re-establish the Quino checkerspot butterfly have been successful.

<u>De-thatching and Herbicide Spraying</u>

Costs associated with removing thatch and spraying nonnative plants with a selective herbicide vary among restoration sites, but depend primarily on the degree to which the natural habitat has been degraded, including the extent of nonnative plant invasion. The cost of removing nonnatives is generally lowest for areas that require only spot spraying of individual plants. Removing plants by hand is costly, especially for large areas. However, hand "weeding" may be necessary for sites occupied by Quino checkerspot butterflies. The de-thatching technique can be used in conjunction with return visits to spray individual nonnative plants; and in some instances a “weed eater” can be used instead of spraying.

The de-thatching technique is typically used only during the first year as part of the site preparation. A crew of approximately ten workers has been used to de-thatch nonnative plants, accomplishing several tasks simultaneously. Activities include weed-whipping the site (4-5 weed-whips can work at one time), raking thatch into piles, collecting thatch and placing it into burlap bundles, and taking the bundles to trucks for removal from the site. Estimated costs per unit area are given below for using the de-thatch and repeat spraying method for sites dominated by nonnative plants, but which still have native plants present.

Using this method, 10 workers can de-thatch approximately 0.4 hectare (1 acre) per day. Costs for the de-thatching range from $4,000 to $5,000 per hectare ($1,600 to $2,000 per acre) (based on a average $20 per hour billing rate for the laborers and supervision time). The work can be physically demanding, especially if the thatch material has to be hauled out of steep canyons. If removing the material is not possible, it can be placed into piles and composted on the site. The nonnative plants that germinate later from the piles will need to be controlled because some nonnative plant seeds will remain. After sufficient rains have fallen in winter, nonnative plant seedlings will require control by return visits to spray Roundup© or other, more selective, herbicides to prevent the plants from maturing and producing seeds. Care must be taken to minimize over-spray onto native species. It is imperative that workers are able to recognize nonnative plants and distinguish them from native plants.

For the first 2 seasons after de-thatching, repeat spraying with an appropriate herbicide up to five times in a season costs approximately $8,400 per hectare ($3,400 per acre)in labor (four workers making five spraying visits) and an additional cost of approximately $500 per hectare ($200 per acre) for herbicide (to spray the entire area once). The amount of spray required will be reduced as the season progresses and fewer nonnative plants are present. After the first 2 years, weeding costs decrease each year if the spraying program is timed to kill the nonnative plants before they set seed. Approximate costs of subsequent years relative to the first year of restoration activities are as follows: year 3, 75 percent; year 4, 50 percent; year 5, 33 percent. These proportions of decreasing costs are approximate and will depend on how weedy the site is initially and how diligently follow-up nonnative plant control efforts are completed. If nonnatives are not killed prior to seeding, costs will not decrease as anticipated. The biologist monitoring the project must ensure that subcontractors or volunteers complete work on schedule and that nonnative plants are controlled prior to seed set for the effort to be effective.

For Quino checkerspot butterfly preserve areas, periodic maintenance will likely be required at low levels in perpetuity after the area is turned over to a long-term site manager. The ultimate goal of restoration efforts is to create self-sustaining Quino checkerspot butterfly habitat areas. However, management endowments will likely be needed indefinitely to fund periodic nonnative plant control activities and other habitat management tasks.

One restoration planning strategy to reduce long-term management costs is ensuring that native species occupy the newly opened ground as nonnative plants are controlled. Established native plants provide resistance to nonnative plant invasion because the space is already occupied, but careful planning is required to ensure that appropriate plant species are selected for the restoration sites. For example, certain native shrub species can quickly outcompete small herbaceous annuals such as *Plantago* (plantain) and *Lasthenia* (goldfields), which are important to Quino checkerspot butterflies. Shrubs, including *Artemisia californica* (California sagebrush), can quickly dominate a restoration site recently opened up by nonnative plant control efforts if the sagebrush are seeded densely or are present in adjacent areas.

Many restoration projects tend to encourage growth of native species that provide fast-growing shrub cover. Many restoration and revegetation projects require quick cover to minimize erosion. However, the goal of providing dense cover is quite different from the goals of a Quino checkerspot butterfly restoration project because areas intended for the species must remain open. Therefore, careful selection of plant material must be incorporated early in the restoration planning process. If not carefully planned, a restoration site can be inadvertently directed toward rapid succession from open ground to dense shrub cover, a habitat unsuitable for Quino checkerspot butterflies. Long-term needs of the butterfly must be considered in the restoration planning process. For example, a site that appears suitable for Quino checkerspot butterflies after 2 or 3 years could be completely dominated by shrubs in 10 years if the project is not planned correctly or appropriate maintenance is not conducted. In this situation, the site would no longer provide suitable habitat because shrub density would be excessive. To avoid losing recently restored habitat, long-term monitoring of Quino checkerspot butterfly restoration sites and remedial measures implemented to slow or reverse succession will be needed.

Total Costs Of Habitat Restoration Maintenance and Monitoring

In addition to nonnative plant removal and control costs, restoration efforts for heavily disturbed sites may also include costs for additional site preparation. This preparation may include grading or recontouring the soil to reconstruct mima mound topography in former vernal pool areas that have been disturbed by agricultural activities, off-road vehicle traffic, or grazing. Costs for the transport and placement of rock cobbles may be included if appropriate to the site. For complete reconstruction of Quino checkerspot butterfly habitat (site preparation and implementation, plant production, planting, weeding, monitoring and annual reporting) the costs can range from $75,000 to $125,000 per hectare ($30,000 to $50,000 per acre) (or possibly more for agricultural fields) for 5 years of maintenance and monitoring. Existing occupied or unoccupied habitat that is relatively intact (with mostly native species) will be less expensive and may range from $12,000 to $50,000 per hectare ($5,000 to $20,000 per acre) depending on the specific site conditions.

Adaptive Management

Adaptive management strategies should be used to deal with unforeseen circumstances. This flexibility is especially important in restoration sites that require complete reconstruction from old agricultural fields. Adaptive management can include management/control of selected native species, such as California sagebrush or other native plant species in Quino checkerspot butterfly restoration sites, so that they don't dominate the vegetation. Until the appropriate Quino checkerspot butterfly larval food and adult nectar plants are fully established, monitoring and control of aggressive native species may be required in addition to controlling nonnative plants. Rapid succession from an open-ground habitat to a dense shrub-dominated community can exclude the species' food plants through competition.

Restoration techniques such as heavy mulching of newly planted containers or entire sites are promoted by some ecologists but are usually inappropriate for small native annuals. Similarly, a heavy mulching strategy is not appropriate for restoration of most rare annual and perennial herbs, or for Quino checkerspot butterfly food plants, such as *Plantago* and *Lasthenia*. The use of light, natural mulch made up of salvaged native sticks and branches is acceptable, but a thick mulch is unnecessary to grow many of the native shrubs and annuals.

Selected Literature

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APPENDIX III

The Annual Forbland Hypothesis: An extinct vegetation type in remnant Quino habitat?

Prepared by Dr. Edith Allen, University of California, Riverside.

The Quino checkerspot butterfly uses exotic annual grasslands that still have a component of native forbs. It is likely that the bottomlands that have mostly been disturbed by agriculture and continuous grazing were once dominated by native forbs rather than exotic grasses. This hypothesis is controversial, as the potential natural vegetation of the Los Angeles Basin and the Riverside-Perris plain was considered by Küchler to be coastal sage scrub (Barbour and Major 1977). However, early Spanish explorers such as de Anza in 1775 (from the diary of Friar Font, translated by Bolton 1930) noted that this region had colorful fields of flowers. Similar observations were made during the late 1700's in northern Baja California; springtime brought a large diversity of colorful flowers to the bottomlands, while shrubs were mentioned for the hillier uplands (Minnich and Vizcaino 1998). It is apparent that if these forblands once existed, they are now a virtually extinct vegetation type. A present day analogue to these forblands exists in the California Poppy Reserve on the west edge of the Antelope Valley, and in the Carrizo Plain of the San Joaquin Valley. These areas are still dominated by native wildflowers in the spring rather than shrubs or grassland, although nonnative plants are a large component of the vegetation. By contrast, in the Perris Plain, Otay Mesa, and Marron Valley the exotic annuals dominate in the lowlands. Although pockets of remnant forblands with lower levels of nonnative invasion can be found in bottomland areas of western Riverside County (*e.g.* an approximately 0.4-ha [1-acre] poppy field in Kabian park, north of Railroad Canyon Reservoir), these areas are rapidly disappearing (A. Anderson pers. observ. 2000). Unfortunately it is possible that in some areas where nonnative plant invasion is slowest and remnant forbland components persist (*i.e.* where semiarid soils dry quickly), host plants may not remain edible long enough to support larvae to maturity. *Plantago erecta* (dwarf plantain) is often considered a plant of clay soils (although Jepson states that it ranges from sand to clay, and it occurs locally in decomposed granites). In areas where *P. erecta* is restricted to clay soils, it would be interesting to test the hypothesis that it is restricted there by weed competition.

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Bolton, H. E. 1930. Anza's California expeditions. v.4. Font's complete diary of the Second Anza expedition. University of California Press. Berkeley, California.

Minnich, R. A., and E. F. Vizcaíno. 1998. Land of chamise and pines: historical accounts and current status of northern Baja California's vegetation. University of California Press. Berkeley, California.

APPENDIX IV
Glossary of Terms

Cryptogamic crust: A tightly bound mesh of various cyanobacteria, lichens, mosses, and fungi holding the soil down. These crusts prevent soil erosion and provide a hospitable environment for germinating plants. They were probably the first land-based communities of life.

Diapause: A low-metabolic resting state similar to hibernation that enables larvae to survive for months to years without feeding.

Ecological connectivity: The amount of undeveloped wildlands between two areas. May or may not include landscape connectivity (connected habitat patches). Habitat areas or populations lacking ecological connectivity are termed completely isolated.

Extinction: Global disappearance of a species or subspecies.

Extirpation: Disappearance of a population.

Forbland: A vegetation community dominated by forbs (broad-leaved herbaceous plants).

Habitat connectivity: The degree of fragmentation within habitat patches. If roads or other development occurs within a habitat patch to the point that adults cannot move freely between micro-patches of larval host plants and other required resources, then one habitat patch may effectively become two or more with intervening areas becoming dispersal areas that support limited exchange between habitat patches. Habitat patches with poor habitat connectivity are termed fragmented, and are generally prone to higher levels of ongoing degradation.

Instar: The period between hatching from the egg to first molt (shedding skin) in larvae, and between molts after that.

Landscape connectivity: The degree of linkage between habitat patches joined by dispersal areas. The number of linked habitat patches and their distance from each other determines the landscape connectivity of an area or a metapopulation. Habitat patches completely lacking landscape connectivity are termed isolated.

Larva: An immature butterfly, a caterpillar.

Larval host plant: Any plant that caterpillars consume.

Levins-style metapopulation: A theoretical metapopulation in which each local population has an equal probability of extinction. Each habitat patch is equally likely to provide immigrants for recolonization of neighbor patches temporarily not supporting larval development, and therefore is equally important. The likelihood of metapopulation extirpation is equally increased for each habitat patch rendered permanently unsuitable. The model assumes that habitat patches are equally connected to each other, and departure from this model occurs whenever patches are fundamentally different in quality (*e.g.* size, host plant density), or distribution of patches is clumped in space.

Mainland-island metapopulation: A metapopulation containing one or more very large habitat patches/populations (the mainland) with a lower risk of extirpation, and other, smaller (island) habitat patches/populations with higher individual risks of extirpation than the mainland population due to their size. This type is slightly different from the "source-sink" model, in that island populations can have the same growth rates and rates of immigration and emigration per unit habitat patch area as the mainland patch. Island populations may be collectively just as important to metapopulation persistence as the mainland population is, and they are likely to serve as sources.

Metapopulation: A population that is composed of a number of local populations. Interaction of individuals among local populations is reduced compared to interaction within local populations. Individuals interact among local populations just enough to reduce the extinction probability of the metapopulation compared to the extinction probability of any local population. In this case interaction specifically refers to emigrants re-colonizing neighboring habitat patches where the local population has been extirpated, and not simply occasional exchange of genetic material.

Metapopulation distribution: The maximum long-term "footprint" of a metapopulation, comprising the area covered by a network of habitat patches (both supporting and temporarily not supporting larval development), and including all the habitat patches that could support larval development over an approximate time-scale of 50 years. It is assumed that long-term mainland-island metapopulation resilience requires butterfly densities to periodically reach their maximum distribution, and therefore the maximum number of habitat patches supporting larval development. Short-term mainland-island metapopulation distributions will tend to fluctuate as much in size as in shape. Levin's-style metapopulations will generally maintain a constant number of habitat patches supporting larval development, therefore the approximate size of the extant distribution will remain constant, but not the shape. The location of habitat patches occupied by larvae will shift from year to year, changing the shape of the short-term distribution over time, but the long-term metapopulation distribution does not change. Both metapopulation models (Levin's and mainland-island) are opposite extremes of the theoretical continuum, and the dynamics/distribution of most metapopulations fall somewhere in-between the two. Local populations within a metapopulation distribution may exhibit dynamics of all three models, Levin's, mainland-island, and source-sink. For example, a distribution may contain one large habitat patch with a local population that has a low probability of extirpation and emigration exceeds immigration, a cluster of habitat patches with equal, intermediate rates of local population extirpation (immigration is equal to emigration), and several habitat patches with high rates of extirpation where immigration exceeds emigration.

Mortality sink: Any location where butterflies experience a high death rate, often, but not necessarily attractive to adults. Examples of mortality sinks include roads that fragment habitat patches, or patches of host plant that are regularly grazed. Different from habitat patches that support local sink populations within source-sink metapopulations. Sink populations are defined by emigration and immigration rates.

Occurrence complex: A spatially clustered set of confirmed Quino checkerspot butterfly observation or collection records that delineate putative short-term pan-mictic population or metapopulation distributions. We used 1-kilometer (0.6-mile) radii around confirmed observations to map occurrence complexes. This distance delineates the area within which we would expect to find the habitat patch associated with the observed butterfly (Gilbert and Singer 1973, Harrison *et al.* 1988, Harrison

1989). Occurrences within 2 km (1.2 mi) of each other are considered to be part of the same occurrence complex because such observations are proximal enough that the observed butterflies would have come from the same population (Ehrlich and Murphy 1987, Harrison *et al.* 1988, Harrison 1989).

Pan-mictic population: A population inhabiting a single isolated (possibly very large) habitat patch, where all individuals have an equal probability of interaction. Although habitat elements (*e.g.* larval host plants) and larval residents may be patchily distributed, adults are able to move freely and frequently between them within a season (definition of a habitat patch based on butterfly use and genetic exchange).

Population distribution. See also Metapopulation Distribution. The maximum long-term "footprint" (geographic area occupied at any time over approximately 50 years) of a pan-mictic population or metapopulation, as delineated and verified by research and monitoring. Occurrence complexes serve as preliminary estimates of population or metapopulation distribution boundaries.

Population site: An area (e.g., vicinity of Lake Mathews) where we have at least strong qualitative information indicating that good habitat remains, and there was a well-documented historic population as recently as the 1980's, but where we have no recent occurrences to use to map an occurrence complex. By comparison, in occurrence complexes recent occupancy (1990's or later) is certain. Re-introduction is necessary to recover the species.

Primary host plant species: Species of host plant on which adult female butterflies deposit eggs, and that caterpillars consume when they hatch.

Pupa: A chrysalis, sometimes mistakenly called a cocoon (cocoons are pupae with an outer silken layer spun by moth caterpillars).

Resilience:

- In general, the ability of a Quino checkerspot butterfly metapopulation or population to survive periodic extreme and unpredictable environmental circumstances and persist long-term (50+ years) in an ecosystem not compromised by human impacts.

- Resilient Quino checkerspot butterfly populations are characterized by the potential to rapidly increase in density under favorable conditions after being seriously reduced, and the ability to continue diapause and/or disperse to more favorable habitat patches when their natal one becomes too densely occupied or otherwise unfavorable. Dispersal events primarily serve to recolonize habitat patches where local populations were extirpated by catastrophic events such as fire, or prolonged unfavorable environmental conditions. Diapause allows local populations to persist in habitat patches that are not favorable for less prolonged periods (maximum number of years unknown). For a general explanation of ecological concepts from which this characterization was derived see Strong (1986).
- For recovery monitoring purposes resilience is demonstrated if a decrease in the number of habitat patches supporting larval development (as demonstrated by adult delectability) within a occurrence complex or population (metapopulation or pan-mictic population) is followed by increases of approximatly equal, or greater, magnitude over a 15-year period without augmentation, or over a 10-year period with augmentation. The percent of patches that are occupied should be estimated by surveys in a sample of no less than 50 percent of the total number of habitat patches identified within a population distribution. Occupancy for the purpose of population resilience monitoring must include adults (reproductive individuals) and pre-diapause larval clusters (their offspring). The surveyed sample of habitat patches must be distributed as equally as possible across a metapopulation distribution to avoid error from possible correlation of suitability between proximal patches.

<u>Secondary host plant species</u>: Species of host plants that caterpillars consume, but on which adult female butterflies do not deposit eggs.

<u>Source-sink metapopulation:</u> A metapopulation composed of local populations, one or more of which are sources of colonization for other, usually dependent, sink populations. In source populations, emigration exceeds immigration, in sink populations, immigration exceeds emigration, and the sink populations are dependent, at least intermittently, on source populations to maintain a nonnegative growth rate. It would be a mistake to assume source populations are more stable, as the status of local populations can change and may even be reversed over time, as changing environmental or density-dependent factors alter the growth rates of

local populations. Even if immigration exceeded emigration in a sink, as long as they produce some emigrants, they may recolonize neighboring habitat patches (they are just less likely to do so than source populations). Only complete mortality sinks, habitats that always attract dispersing individuals that would otherwise colonize more suitable habitat, and do not produce emigrants capable of colonizing neighboring habitat patches, are likely to reduce rather than enhance metapopulation resilience.

APPENDIX V
Unconfirmed Quino Checkerspot Butterfly Observations

Some Quino checkerspot butterfly observations have been reported that, although they were convincing, were not accompanied by enough evidence to be considered conclusive. To be considered conclusive, reports must be made by a biologist permitted to survey for Quino checkerspot butterflies, and be in the general proximity of previously confirmed recent (1990's) Quino checkerspot populations (*e.g.* within recovery units). If observations do not meet the above criteria, evidence such as concurrent or subsequent observations by another permitted biologist or a photograph and field notes must have been provided (*e.g.* the San Vicente Reservoir Occurrence Complex discovered in 2001). Three unconfirmed reports are worth mentioning in particular. In 1992 (pre-listing) a now-permitted biologist reported observing what he believes was a Quino checkerspot butterfly on a hilltop north of San Vicente Reservoir (Pacific Southwest Biological Services 1993, D. Mayer, pers comm. 2003). The reported San Vicente Reservoir observation was located on the southern border of the San Vicente Reservoir Occurrence Complex (Figure 8). In 1999 a permitted U.S. Fish and Wildlife Service staff biologist reported having observed a Quino checkerspot butterfly in the northern region of Sycamore Canyon Open Space Preserve, south of the city of Poway (M. Van Hoffman, pers. comm. 1999). The reported Sycamore Canyon observation was approximately 1 kilometer (0.6 mile) east of the San Vicente Reservoir Occurrence Complex (Figure 8). Also in 1999 a non-permitted biologist who had correctly identified photographs of larvae reported larvae in the Harmony Grove area west of Escondido (C. Hertzog pers comm. 1999). In all cases no photographic documentation was provided, and subsequent searches by permitted biologists in the vicinities did not result in further observations.

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Personal Communications

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APPENDIX VI
Summary of Comments

On February 8, 2001, we released the Draft Quino Checkerspot Butterfly Recovery Plan for a 45 day public comment period that ended March 26, 2001, for Federal agencies, State and local governments, and members of the public (U.S. Fish and Wildlife Service 2001c). Comments were received from three expert biologists, two Federal agencies, four local agencies, four businesses, and one private party. These comments, where appropriate, have been incorporated into the final recovery plan. Many of the comments requested that information from the 2001 Quino checkerspot butterfly flight season be considered and incorporated into the final plan. Much relevant biological information was gathered during the 2001 flight season, and additional biological information not related to the 2001 flight season was also gathered and analyzed. All new information gathered since draft recovery plan publication has been fully considered and incorporated into the final plan; most changes were related to new information. We feel that some comments require a fuller response and explanation, to this end we offer the following responses to comments.

Issue 1: Two commenters thought the plan gave the impression that rare long-distance dispersal and colonization events were not important to the biology of the butterfly, and that closed-canopy woody vegetation presented an impermeable barrier to dispersal. One commenter stated that the importance and possible frequency of long-distance (5-10 km) dispersal events needed to be clearly stated in the plan. He thought there was evidence that Quino checkerspot butterflies semi-regularly, both in the course of aging and under certain environmental conditions, undergo behavioral shifts and enter long-distance dispersal modes.

Service Response: We concur that long-distance dispersal and colonization events probably play important roles in long-term butterfly metapopulation dynamics and persistence, and the degree of rarity of such events has not been quantified. We also concur that closed canopy woody vegetation and similar structures present only dispersal deterrents and not impermeable barriers. As a result the text has been changed to correct any false implications.

Issue 2: One commenter suggested that hilltopping behavior plays a critical role in reproductive success of the Quino checkerspot butterfly, and therefore in its population ecology and conservation planning. He felt the role of this behavior should be stated in the recovery plan, with reduced emphasis on other hypotheses for frequency of butterfly observations on hilltops.

Service Response: We believe that disagreement within the scientific community on the subject of hilltopping stems primarily from the technical definition of the words "hilltopping behavior," and not the use of hilltops as a means of locating mates. Edits were made to better emphasize the nature and importance of hilltops as a resource for the Quino checkerspot butterfly.

Issue 3: The same commenter felt that the threat of global warming was accurately presented, but was given too much weight compared to urban growth and development.

Service Response: We believe sufficient emphasis is given in the plan to threats presented by urban growth and development, and global warming is a future, if not current, threat to the Quino checkerspot butterfly potentially equal to and exacerbated by habitat destruction. We edited the text to better explain current knowledge of the threat of global warming, and added suggestions for how to begin addressing local recovery actions and planning. In most cases recovery actions addressing global warming effects are the same as or reinforce those addressing habitat destruction and development.

Issue 4: Three commenters appeared to have confused the definitions and regulatory implications of recovery units and critical habitat. They thought lands that did not contain habitat should be excluded from areas mapped as recovery units. They were concerned that inclusion of land within a recovery unit meant that land was considered butterfly habitat, and established regulatory protection of the mapped land. One commenter thought that we mapped recovery unit boundaries with the intent of imposing greater regulatory burdens and heightened land use scrutiny within those areas.

Service Response: Recovery plans and recovery units are not regulatory in nature, and are separate from critical habitat designation, which is regulatory. As part of the unique criteria for defining proposed critical habitat for the Quino checkerspot butterfly, mapped areas of possible critical habitat were limited to within mapped draft recovery unit boundaries (U.S. Fish and Wildlife Service 2002a). Therefore, draft recovery unit boundaries limited the total area proposed as critical habitat to those areas that were the focus of draft recovery actions. All other proposed critical habitat criteria were not related to mapped recovery unit boundaries, other than coincidentally. Recovery units do not have hard outer geographic boundaries, unlike critical habitat, and are only partially habitat based. Recovery units in this plan define areas that are the focus of any recovery action, including urban-wildland interface areas that are the focus of educational outreach and cross-boundary management actions. All mapped potential critical habitat should be within recovery units, but not all mapped recovery unit areas are potential critical habitat. Heightened regulatory scrutiny was intended only where regulatory scrutiny is currently inadequate. It was not our intent to create unjustified or redundant regulatory or economic burdens on landowners.

Issue 5: One commenter felt the plan emphasized habitat restoration over preservation, and that this emphasis should be reversed. They said that the plan assumed that a highly manipulated environment will be as suitable for re-colonization by the Quino checkerspot butterfly as intact undisturbed habitat.

Service Response: We do not believe emphasis on either subject was misplaced, and think it is clear that funds should not be spent on restoration of habitat that is not first preserved. We believe that this commenter's objection was partially based on different connotations of the term "restoration." We agree that the first recovery priority must be habitat preservation, but under current conditions all habitat areas will continue to decline in suitability without some restoration-based management activities (including activities such as enhancement and weed control, not just reconstruction of former habitat). It is important that policy makers understand that land acquisition alone is not sufficient for recovery, and that there is no intact, undisturbed habitat left.

Issue 6: The same commenter thought that there should be a recovery task recommending research be done on the effects of herbicides that might be used in restoration activities.

Service Response: We concur that herbicides are an important restoration tool, and research should be done on the effects of herbicides on the Quino checkerspot butterfly. As a result the narrative has been changed to recognize this need for research.

Issue 7: Two commenters thought the draft recovery plan was too vague and lacked specific information needed to determine land preservation priorities. One commenter claimed that the plan failed to provide the clear principles supported by sound science needed to guide landowners and regulators. They expressed discontent with frequent use of the term "may," and speculative language in the recovery strategy.

Service Response: Although we strive to provide detail, when possible and appropriate, our limited knowledge of the species often precludes specific recommendations. We have added some level of detail to the text based on new information and further analysis. We added the conclusion that extinction of the species in the foreseeable future appears to remain a distinct possibility; and any occupied habitat should be preserved unless there is sound scientific evidence indicating it does not contribute to the persistence of a greater population. Although we did describe general principles supported by sound science, detailed explanations of the scientific principles are beyond the scope of this text, and can be found in cited ecological literature. In general, the issue of uncertainty is pervasive in science, and especially in the study of complex ecological systems:

> "There will always be major uncertainties in how ecological systems will respond to management actions and society must make important decisions in the face of such uncertainty. The reason ecology is more difficult is plain: experiments take longer, replication, control, and randomization are harder to achieve, and ecological systems have the nasty habit of changing over time... Rocket scientists have it easy!" (Hillborn and Ludwig, Ecological Applications 3:550; see also Weiner, Journal of Ecology 83:153; Ehrlich, Oikos 63:6)

Predicting how ecological systems will react to management actions is complicated by the extreme difficulty of predicting emergent properties; even if one understands how all the parts will react in isolation under controlled conditions, the system may behave entirely differently because of interactions among components. In cases involving rare endangered species, ecological research is even more difficult to do than usual, and the best scientific information available is often limited. Therefore, with regard to endangered insect species, natural history information, such as current and historic site occupancy information, and probable population trends, must be sufficient sound science upon which to base preliminary recommendations (Ehrlich 1992).

Issue 8: One commenter cited the statement "Undeveloped wildlands adjacent to and between Quino checkerspot metapopulation distributions should be maintained because they contain landscape connectivity essential to other species that are part of the Quino checkerspot habitat community." from the draft recovery plan (p. 51). The commenter pointed out that this statement contained no scientific documentation and claimed that "many such undeveloped wildlands have no habitat components that are supportive of Quino." The commenter claimed the draft recovery plan basically said all undeveloped land should remain so.

Service Response: We agree that the quoted statement should be qualified with regards to feasibility, the text has been edited accordingly. However, we believe it was clear in other sections of the text that we were not advocating a moratorium on development of wildlands, only that wildlands adjacent to and between populations should be spared from development whenever possible. We also respectfully disagree with their statement that "many such undeveloped wildlands have no habitat components that are supportive of Quino. Ecological communities, especially in highly diverse Mediterranean-type climate areas, are complex and composed of thousands of interdependent species evolved to survive in unique and variable environmental conditions; we know very little about many such arthropod species. Species in ecological communities have overlapping, but not identical, distributions within an ecosystem. Species that provide crucial ecological services such as pollination, nutrient cycling, predation, water and soil detoxification, and seed dispersal cannot survive in isolation from each other below the ecosystem level (that is, in part, the definition of a natural ecosystem). Not all species supporting a given Quino checkerspot population could possibly persist entirely within the distribution of the butterfly population. Please refer to the following references for support of our statement: Real and Brown (1991) and Naheed *et al.* (1999). The ultimate purpose of the Endangered Species Act is to prevent the collapse of ecosystems upon which endangered species depend (Section 2(b) of the Endangered Species Act). Preservation of wildlands adjacent to endangered species habitat also supports endangered species by providing insulation from the degrading effects of development on habitat and reduces the need for intensive, expensive management. Effects of adjacent development include habitat destruction and population depletion due to recreational activity, illegal dumping, enhanced invasion of exotic species, external mortality sinks, increased fire frequency, and pollution.

Issue 9: One commenter claimed that all known populations and the best habitat in the South Riverside/North San Diego recovery unit is north of Chihuahua Creek and that the recovery unit boundaries were drawn inconsistently with the way others were drawn, and recommended the boundary be retracted to the creek.

Service Response: We respectfully disagree, and do not believe the recovery unit boundary should be retracted. We have learned much recently about the biology of the Quino checkerspot butterfly and its habitat. We know that some apparent Quino checkerspot butterfly habitat does exist at the southern end, and that the distribution of its newly discovered primary host plant (*A. coulterianum*) also extends to the southern end of the recovery unit. Much of the southern end of the recovery unit is open chaparral habitat similar to known occupied areas to the north. Although it was not explicitly stated in the text, another reason this unit extends so far south of known populations is that the southern area represents bottlenecks between the two mountains (Palomar, Combs Peak area) and the mountains and the desert (Combs Peak area and the Anza Borrego Desert) that are the best possibility for current or future north-south range-wide landscape connectivity.

Issue 10: The same commenter claimed that the proposed North Orange recovery unit is not viable because it is isolated from other recovery units and has a history of extirpation, despite large areas of habitat. They recommended that the proposed recovery unit be dropped from the plan.

Service Response: We respectfully disagree. We are not certain that the Quino checkerspot butterfly has been extirpated from the proposed recovery unit, as no comprehensive surveys have been conducted. The recovery unit was proposed because we believe it may be viable. Historic extirpation that occurred at Black Star Canyon appears to have been caused primarily by manageable circumstances (fire, habitat degradation, and destruction of lower-elevation source populations, see discussion in section I.C.5, Metapopulation Resilience). The probability of this recovery unit being viable was recently increased by the Irvine Company's gift of the Fremont Conservation Area to The Nature Conservancy. Most Quino checkerspot butterfly populations will require management to persist in the future, and viability for recovery purposes does not depend on complete self-sufficiency of populations. We believe the proposed recovery unit is a large and protected enough area to support an experimental or managed Quino checkerspot butterfly metapopulation in isolation from other recovery units.

Issue 11 Two commenters requested that the implementation schedule provide more comprehensive and rigorous cost estimates.

Service Response: We provided the best cost estimates possible within the time, resource, and knowledge constraints under which the draft recovery plan was developed. It is not possible to provide realistic estimates of the cost of implementing many actions because costs depend on the outcome of other actions that are of unknown magnitude. We have revised cost estimates wherever it was possible and appropriate.

Issue 12: One commenter appeared to be concerned that the task specifying the Service "enter into dialogue" with the Cahuilla Band of Mission Indians was given too low a priority ranking and was listed last in the implementation schedule. They also stated that coordination with the tribe should have occurred prior to release of the draft plan, and any efforts to conserve endangered species on the reservation will have to occur through voluntary actions of the tribe.

Service Response: The recovery action priorities are based entirely on biological necessity and current threats. Although we did believe occupied habitat on the Cahuilla Indian Reservation was crucial to survival and recovery of the species, we did not believe current threats to the butterfly were great enough on the reservation to warrant a high priority. Priorities are assigned as follows (pg. 92):

1 = An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2 = An action that must be taken to prevent a significant decline in species' population, habitat quality, or some other significant negative impact short of extinction.

3 = All other actions necessary to meet the recovery objectives.

Also, the order in which primary recovery actions are listed in the implementation schedule within the prioritization categories is not chronological or priority based. Because the Tribal representatives informed us at a meeting in 2002 that occupied habitat on the reservation is planned for economic activities and fire-break clearing (threats we did not know of before), and we believe maintenance of this occupied habitat is probably necessary to prevent a significant decline of the species' habitat quality and population, we have changed the recovery action to a priority 2.

We regret the lack of coordination with the Tribe prior to release of the draft recovery plan; unfortunately our attempts to do so were not successful. One of our staff members did establish initial contact with the tribal grants administrator (when attempting to contact the tribal spokesperson) during development of the draft recovery plan, and informed him that we were working on the plan, and that there might be Quino checkerspot butterflies on the reservation. However, subsequent attempts by other Carlsbad Fish and Wildlife Office staff members to establish contact with tribal representatives prior to draft recovery plan publication were unsuccessful. We have subsequently contacted and initiated discussion with the Cahuilla Band of Indians, and offered to assist with preparation of an environmental management plan for the reservation. We also refined our recommendations to specify solicitation of voluntary conservation efforts.

APPENDIX VII. Summary of Threats and Recommended Recovery Actions

LISTING FACTOR	THREAT	RECOVERY CRITERIA	TASK NUMBERS
A	Urban and agricultural development*	1, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 6.3
A	Grazing*	3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7.1, 1.7.2, 6.3
A	Displacement of larval food plants by exotic plants*	2, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7.1, 1.7.2, 6.3, 6.7
A	Trash dumping*	3, 7	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 5.1, 5.2, 5.3, 9
A	Off-road vehicle use*	3, 7	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 5.1, 5.2, 5.3, 5.4
A, E	Habitat fragmentation*	1, 2, 3, 4, 5	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 6.1, 6.2, 6.3, 6.4, 6.5, 7, 8, 11, 12
A, E	Increased fire frequency/severity*	3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6
B	Over-collection by butterfly collectors*	2, 7	5.1, 5.2, 5.3
B	Vandalism by landowners*	1, 3, 7	5.1, 5.2, 5.3
C	Predation by introduced insects associated with exotic plants*	2, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7.1, 1.7.2, 6.3, 6.7
D	Lack of adequate protection by CESA, CEQA, and NEPA*	N/A	Beyond scope of recovery plan.

LISTING FACTOR	THREAT	RECOVERY CRITERIA	TASK NUMBERS
D	Lack of regional conservation planning programs*	1, 3	1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 10, 13
E	Drought*	2, 3, 5	6.6, 7
E	Genetic drift and inbreeding associated with low population size*	1, 2, 3, 4, 5, 6	3, 4, 7, 8, 11
E	Elevated carbon dioxide levels	2	6.8
E	Nitrogen fertilization	2	6.8

Listing Factors:
A. The Present or Threatened Destruction, Modification, or Curtailment Of Its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, Educational Purposes (not a factor)
C. Disease or Predation
D. The Inadequacy of Existing Regulatory Mechanisms
E. Other Natural or Manmade Factors Affecting Its Continued Existence
* Identified as threat in listing rule.

EXHIBIT 3

SAN DIEGO COUNTY

VERY HIGH FIRE HAZARD SEVERITY ZONES IN LRA
As Recommended By CAL FIRE

Government Code 51175-89 directs the California Department of Forestry and Fire Protection (CAL FIRE) to identify areas of very high fire hazard severity zones within Local Responsibility Areas (LRA). Mapping of the areas, referred to as Very High Fire Hazard Severity Zones (VHFHSZ), is based on data and models of, **potential** fuels over a 30-50 year time horizon and their associated expected fire behavior, and expected burn probabilities to quantify the likelihood and nature of vegetation fire exposure (including firebrands) to buildings. Details on the project and specific modeling methodology can be found at http://frap.fire.ca.gov/projects/hazard/fhz.html. Local Responsibility Area VHFHSZ maps were initially developed in the mid-1990s and are now being updated based on improved science, mapping techniques, and data.

In late 2005 to be effective in 2008, the California Building Commission adopted California Building Code Chapter 7A requiring new buildings in VH FHSZs to use ignition resistant construction methods and materials. These new codes include provisions to improve the ignition resistance of buildings, especially from firebrands. The updated very high fire hazard severity zones will be used by building officials for new building permits in LRA. The updated zones will also be used to identify property whose owners must comply with natural hazards disclosure requirements at time of property sale and 100 foot defensible space clearance. It is likely that the fire hazard severity zones will be used for updates to the safety element of general plans.

This specific map is based on a geographic information system dataset that depicts final CAL FIRE recommendations for Very High FHSZs within the local jurisdiction. The process of finalizing these boundaries involved an extensive local review process, the details of which are available at http://frap.cdf.ca.gov/projects/hazard/btnet/ (click on "Continue as guest without logging in"). Local government has 120 days to designate, by ordinance, very high fire hazard severity zones within its jurisdiction after receiving the recommendation. Local government can add additional VHFHSZs. There is no requirement for local government to report their final action to CAL FIRE when the recommended zones are adopted. Consequently, users are directed to the appropriate local entity (county, city, fire department, or Fire Protection District) to determine the status of the local fire hazard severity zone ordinance.

Projection Albers, NAD 1927
Scale 1: 150,000
at 46" x 34"
June 12, 2009

Arnold Schwarzenegger, Governor,
State of California
Mike Chrisman, Secretary for Resources,
The Natural Resources Agency
Del Walters, Director,
Department of Forestry and Fire Protection

MAP ID: FHSZL_MAP

DATA SOURCES
CAL FIRE Fire Hazard Severity Zones (FHSZL06_3)
CAL FIRE State Responsibility Areas (SRA05_5)
CAL FIRE Incorporated Cities (Incorp07_3)
PLSS (1:100,000 USGS, Land Grants with CAL FIRE grid)

EXHIBIT 4

SAN DIEGO COUNTY

FRAP
Fire and Resource Assessment Program
California Department of Forestry and Fire Protection

FIRE HAZARD SEVERITY ZONES IN SRA

Adopted by CAL FIRE on November 7, 2007

FIRE HAZARD SEVERITY ZONES in State Responsibility Area (SRA)

- Moderate
- High
- Very High

FIRE PROTECTION RESPONSIBILITY

- Federal Responsibility Area (FRA)
- Local Responsibility Area (LRA) - Unincorporated
- Local Responsibility Area (LRA) - Incorporated

Public Resources Code 4201-4204 direct the California Department of Forestry and Fire Protection (CAL FIRE) to map fire hazard within State Responsibility Areas (SRA), based on relevant factors such as fuels, terrain, and weather. These statutes were passed after significant wildland-urban interface fires; consequently these hazards are described according to their potential for causing ignitions to buildings. These zones referred to as Fire Hazard Severity Zones(FHSZ), provide the basis for application of various mitigation strategies to reduce risks to buildings associated with wildland fires. The zones also relate to the requirements for building codes designed to reduce the ignition potential to buildings in the wildland-urban interface zones.

These maps have been created by CAL FIRE's Fire and Resource Assessment Program (FRAP) using data and models describing development patterns, estimated fire behavior characteristics based on potential fuels over a 30-50 year time horizon, and expected burn probabilities to quantify the likelihood and nature of vegetation fire exposure to new construction. Details on the project and specific modeling methodology can be found at http://frap.cdf.ca.gov/projects/hazard/methods.htm.

The version of the map shown here represents the official "Maps of Fire Hazard Severity Zones in the State Responsibility Area of California" as required by Public Resources Code 4201-4204 and entitled in the California Code of Regulation, Title 14, Section 1280 Fire Hazard Severity Zones, and as adopted by CAL FIRE on November 7, 2007.

An interactive system for viewing map data is hosted by the UC Center for Fire at http://firecenter.berkeley.edu/fhsz/

Questions can be directed to David Sapsis, at 916.445.5369, dave.sapsis@fire.ca.gov.

Projection Albers, NAD 1927
Scale 1: 150,000
at 46" x 34"
November 06, 2007

Obtain FRAP maps, data, metadata and publications on the Internet at http://frap.cdf.ca.gov
For more information, contact CAL FIRE-FRAP, PO Box 944246, Sacramento, CA 94244-2460, (916) 327-3939.

Arnold Schwarzenegger, Governor,
State of California
Mike Chrisman, Secretary for Resources,
The Resources Agency
Ruben Grijalva, Director,
Department of Forestry and Fire Protection

MAP ID: FHSZS_MAP

DATA SOURCES
CAL FIRE Fire Hazard Severity Zones (FHSZS06_3)
CAL FIRE State Responsibility Areas (SRA05_5)
CAL FIRE Incorporated Cities (Incorp07_3)
PLSS (1:100,000 USGS, Land Grants with CAL FIRE grid)

EXHIBIT 5

Environmental Impacts of

Polyvinyl Chloride (PVC) Building Materials

A briefing paper for the Healthy Building Network

by

Joe Thornton, Ph.D.

This report was prepared by the author and does not represent the opinions of Columbia University, the Trustees of Columbia University, or the Columbia Earth Institute.

About the Author

Joe Thornton, Ph.D., is a postdoctoral research scientist in Columbia University's Earth Institute and Department of Biological Sciences. His research focuses on the health and policy implications of global chemical pollution and on the molecular evolution of animal endocrine systems. He holds Ph.D., M.A., and M.Phil. degrees in Biological Sciences from Columbia University and a B.A. from Yale University.

Dr. Thornton is the author of *Pandora's Poison: Chlorine, Health, and a New Environmental Strategy* (MIT Press 2000), which the British scientific journal *Nature* has called "a landmark book which should be read by anyone wanting to understand the environmental and health dangers of chlorine chemistry." From the late 1980s to the mid-1990s, Thornton was research analyst and then research coordinator for Greenpeace's U.S. and international toxics campaigns. There, he authored seminal reports and articles on organochlorines, dioxin, breast cancer, waste incineration, risk assessment, and the precautionary principle. After joining Columbia University in 1995, Dr. Thornton co-authored the article and American Public Health Association resolution that launched the campaign to eliminate polyvinyl chloride (PVC) products from medical devices due to their central role in dioxin formation in medical waste incinerators. He has spoken before the U.S. Congress, the EPA Science Advisory Board, the American Association for the Advancement of Science, the American Public Health Association, the International Joint Commission, and for a variety of other organizations and audiences. His work has been published in numerous scientific journals, including *Proceedings of the National Academy of Sciences, Annual Review of Genomics and Human Genetics, Public Health Reports, Bioessays, Systematic Biology,* and *International Journal of Occupational and Environmental Health.*

CONTENTS

Summary of Findings

In the past 40 years, polyvinyl chloride plastic (PVC) has become a major building material. Global vinyl production now totals more than 30 million tons per year, the majority of which is directed to building applications, electronics, and furnishings.

The manufacture, use, and disposal of PVC poses substantial and unique environmental and human health hazards. Across the world, governments, companies, and scientific organizations have come to recognize the hazards of PVC. In most of Europe, governments have eliminated certain PVC uses for environmental reasons, and several countries have ambitious programs to reduce PVC use. Scores of communities have PVC avoidance policies, and dozens of green buildings have been built with little or no PVC materials. Firms in a variety of industries have announced measures to reduce PVC consumption and are using or producing alternative materials in a variety of product sectors, including building materials.

The following major hazards of the PVC lifecycle are discussed in this report:

PVC and chlorine. Vinyl is the largest use of chlorine gas in the world, consuming about 40 percent of total chlorine production, or approximately 16 million tons of chlorine per year worldwide. PVC is the largest production-volume organochlorine—a large class of chemicals that have come under scientific and regulatory scrutiny in the past decade because of their global distribution and the unusually severe hazards they pose. Vinyl is the only major building material that is an organochlorine. Alternative materials—including most other plastics—do not contain chlorine and therefore do not pose the hazards discussed in this report.

Formation of by-products. Large quantities of hazardous organochlorine by-products are formed accidentally and released into the environment at numerous points in the vinyl lifecycle.

- Formation of hazardous organochlorine by-products begins with the production of chlorine gas. Extremely large quantities—on the order of one million tons per year—of chlorine-rich hazardous wastes are generated in the synthesis of ethylene dichloride (EDC) and vinyl chloride monomer (VCM)—the feedstocks for PVC. Still more by-products are created and released into the environment during the incineration of hazardous wastes from EDC and VCM production, including the incineration of vinyl products in the waste stream, the recycling of vinyl-containing metal products by combustion, and the accidental burning of PVC in building, warehouse, or landfill fires.

- These chemical mixtures include such extremely hazardous and long-lived pollutants as the chlorinated dioxins (polychlorinated dibenzo-p-dioxins), chlorinated furans (polychlorinated dibenzofurans), polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), and octachlorostyrene (OCS). In addition, large portions of these mixtures consist of chemicals that have not yet been identified or tested.

Hazards of by-products. The by-products of the vinyl lifecycle are of great concern because many of their components are highly persistent, bioaccumulative, and toxic.

- Persistent substances resist natural degradation, build up over time in the environment, and are distributed long distances by currents of air and water. Many of the by-products of the PVC lifecycle are now ubiquitous global pollutants, found not only in industrialized regions but also in the planet’s most remote ecosystems. Absolutely every person on earth is now exposed to these substances.

- Bioaccumulative substances build up in the tissues of living things. Most bioaccumulative substances, including many formed during the PVC lifecycle, are oil-soluble chemicals that magnify as they move up the food chain, reaching concentrations in species high on the food chain that are millions of times greater than levels in the ambient environment. These substances also cross the placenta easily and concentrate in the breast milk of humans and other mammals.

- Toxic substances cause harmful effects on the body. The feedstocks and by-products of the vinyl lifecycle have been shown to cause a range of health hazards—in some cases at extremely low doses—including birth defects, cancer, disruption of the endocrine system, impaired child development, neurotoxicity (damage to the brain or its function), reproductive impairment, and suppression of the immune system.

Vinyl and dioxin. Among the most important by-products of the PVC lifecycle are dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxins) and a large group of structurally and toxicologically related compounds, collectively called dioxins. Dioxins are never manufactured intentionally but are formed accidentally whenever chlorine gas is used or chlorine-based organic chemicals are burned or processed under reactive conditions.

- Formation of considerable quantities of dioxins has been documented during numerous stages of the vinyl lifecycle, including production of chlorine, synthesis of the feedstocks EDC and VCM, burning of vinyl products in accidental fires, and incineration of vinyl products and the hazardous wastes from PVC production.

- Vinyl is the predominant chlorine donor and therefore a major cause of dioxin formation in most of the leading dioxin sources that have been identified. When its entire lifecycle is considered, vinyl appears to be associated with more dioxin formation than any other single product.

- Dioxins are true global pollutants, now found in the tissues of whales in the deep oceans, polar bears in the high Arctic, and every human being on earth. Human infants receive particularly high doses—orders of magnitude greater than those of the average adult—because dioxins cross the placenta easily and concentrate in breast milk.

- Dioxin is the most potent synthetic carcinogen ever tested in laboratory animals and is a known human carcinogen.

- Human development, reproduction, and the immune and endocrine systems are highly sensitive to dioxin, which causes health damage and functional impairment at infinitesimally low doses (in the low parts per trillion, or ppt). Toxicological studies have not been able to establish a "threshold" dose below which dioxin has no biological impact.

- The dioxin "body burden" of the general population of the United States – the load of dioxin-like compounds that have accumulated in the tissues of people with no special exposures -- is already in the range at which adverse health impacts occur in laboratory animals. Dioxin exposure of the average American already poses a calculated cancer risk of one in 1,000 to one in 100—thousands of times greater than the usual standard for an "acceptable risk."

- Current levels of dioxin therefore represent a public health risk. Efforts to reduce dioxin formation at the source should be environmental and public health priorities. As a leading cause of dioxin generation, PVC should be addressed as part of this program.

Phthalate plasticizers. In its pure form, PVC is rigid and brittle. To make flexible vinyl products, such as floor tiles, roofing materials, and wall coverings, plasticizers must be added to PVC in large quantities—up to 60 percent of the final product by weight. The dominant group of plasticizers used in vinyl is a class of compounds called phthalates, which pose considerable health and environmental hazards. Vinyl is the only major building product using phthalates extensively, accounting for about 90 percent of total phthalate consumption. More than 5 million tons of phthalates are used in vinyl every year.

- Phthalates have become global pollutants that are moderately persistent and moderately bioaccumulative under some conditions. They can be found in the water of the deep oceans, air in remote regions, and the tissues and fluids of humans. Body burdens of some phthalates have recently been found to be surprisingly high in the bodies of the general U.S. population. Infants and toddlers are subject to exposures several times higher than those of the average adult.
- Millions of pounds per year of phthalates are released into the environment during the formulation and molding of vinyl products. Phthalates are also released when vinyl is disposed of in landfills or incinerators or when PVC products burn accidentally. More than 80 million tons of phthalates are estimated in the stock of PVC products now in use in buildings and other applications.
- Phthalates are not chemically bonded to the plastic but are mixed with the polymer during formulation. They therefore leach out of the plastic over time into air, water, or other substances with which vinyl comes in contact.
- Phthalates cause a range of health effects. Phthalates used in PVC have been found to damage the reproductive system, causing suppressed ovulation, infertility, reduced sperm count, testicular damage, and abnormal development and function of the testes and male reproductive tract in laboratory animals, in which they are also carcinogens.
- An expert committee of the National Toxicology Program recently reviewed the hazards of diethylhexyl phthalate (DEHP, the most common vinyl plasticizer) and expressed "concern" that exposure of infants and toddlers in the general U.S. population may adversely affect development of the male reproductive tract development, as well as "concern" that exposure of pregnant and nursing women may impair the development of their offspring. The average American's dose of the plasticizer DEHP is now approximately equal to the Environmental Protection Agency's (EPA's) reference dose—the maximum "acceptable" exposure based on studies of health impacts in laboratory animals.

Lead and other stabilizers. Because PVC catalyzes its own decomposition, metal stabilizers are added to vinyl for construction and other extended-life applications.

- Common PVC additives that are particularly hazardous are lead, cadmium, and organotins, with global consumption of each by vinyl estimated in the thousands of tons per year.
- Because metals do not degrade in the environment, all three of the major PVC stabilizers have become global pollutants.
- Lead is a highly potent developmental toxicant, damaging brain development and reducing the cognitive ability and IQ of children, even in infinitesimal doses. Cadmium is a potent neurotoxin and carcinogen, and organotins can suppress immunity and disrupt the endocrine system.
- Metal stabilizers are released from vinyl products when they are formulated, used, and disposed. Releases of lead stabilizers from interior vinyl building products have been documented. Metals cannot be destroyed by incineration but are released entirely into the environment via air emissions or ash residues. Trash incinerators are a dominant source of lead and cadmium pollution, and PVC contributes a significant portion of the feed of these metals—including an estimated 45,000 tons of lead each year—to incinerators.
- Accidental fires are also major potential sources of lead, cadmium, and organotins releases. In a fire, metals in PVC will be released to the environment. An astounding 3.2 million tons of lead

are present in the current stock of PVC in use. Potential lead releases from this stored PVC must be viewed as a major potential health hazard.

Indoor air quality. Flexible vinyl products appear to contribute to the health hazards of poor indoor air quality by releasing phthalates and facilitating the growth of hazardous molds.

- The phthalates in PVC are released into the building environment. Phthalate levels in indoor air for buildings with PVC are typically many times higher than those for outdoor air. Phthalate accumulation in suspended and sedimented indoor dusts is particularly high, with concentrations in dust as high as 1,000 parts per million (ppm).
- Preliminary evidence indicates that PVC-related phthalate exposure may be linked to asthma. In laboratory animals, metabolites of phthalates used in vinyl cause asthma-like symptoms through a well-described inflammatory mechanism. Three separate epidemiological studies have found that human exposure to PVC in buildings causes significantly elevated risks of asthma and other pulmonary conditions, including bronchial obstruction, pneumonia, prolonged cough, wheezing, and irritation of the nasal passages and eyes.
- Metal stabilizers—particularly lead, cadmium, and organotins—can also be released from vinyl products. Lead has been found to be released into air from vinyl window blinds and into water from PVC pipes. Toxicological effects of these substances include developmental, neurological, and reproductive damage.
- Because vinyl wall coverings form a barrier impermeable to moisture, they encourage the growth of molds on wall surfaces beneath the vinyl—particularly in buildings where air conditioning or heating systems produce significant temperature and humidity differentials between rooms and wall cavities. Some molds that grow beneath vinyl produce toxic substances that are released into indoor air. Numerous liability suits are active on the link between vinyl-produced molds and respiratory and neurological symptoms among exposed populations. Vinyl has been cited as the interior building material most likely to facilitate the growth of these molds.

Occupational and local environmental exposures. In the production of PVC, many thousands of tons per year of the feedstocks EDC and VCM are released into the workplace and into local environments, posing health risks to workers and communities:

- Both EDC and VCM are known human carcinogens. They are toxic to the nervous system and cause a variety of other negative impacts on human health.
- Increased risks of liver cancer and brain cancer have been documented among workers exposed to VCM. There is preliminary evidence that workers involved in the manufacture of PVC products have elevated risks of testicular cancer.
- Although workplace exposures in U.S. chemical and plastics facilities have been significantly reduced from the levels of the 1960s, occupational exposure to VCM remains dangerously high in some facilities in Eastern Europe and Asia. Further, there is no threshold below which VCM does not increase the risk of cancer, so current exposures in the United States continue to pose cancer hazards to workers.
- Severe contamination of communities and waterways in the vicinity of VCM production facilities has been documented. In Louisiana, significantly elevated levels of dioxins have been found in the blood of people living near a VCM facility, several communities have been evacuated due to VCM contamination of groundwater, and extremely high levels of highly persistent,

bioaccumulative by-products attributable to VCM production have been found in local waterways. In Europe, VCM production facilities have caused severe regional contamination with dioxins and other by-products.

Energy consumption. Chlorine production is one of the world's most energy-intensive industrial processes, consuming about 1 percent of the world's total electricity output. Chlorine production for PVC consumes an estimated 47 billion kilowatt-hours per year—equivalent to the annual total output of eight medium-sized nuclear power plants.

Mercury pollution. The mercury-based process for chlorine production accounts for about one-third of world chlorine output. In this process, large quantities of mercury are released into the environment. Mercury is now a global pollutant that causes severe reproductive, developmental, and neurological impacts at low doses. Each year, the vinyl lifecycle is associated with the continuing release of many tons of mercury into the environment.

Extreme difficulty of recycling. Very little PVC is recycled, and this fact is unlikely to change in the foreseeable future. Because each PVC product contains a unique mix of additives, postconsumer recycling of mixed PVC products is difficult and cannot yield vinyl products with equivalent qualities to the original. Even in Europe, where PVC recycling is more advanced than in the United States, less than 3 percent of postconsumer PVC is recycled, and most of this is "down-cycled" into other products—meaning there is no net reduction in the production of virgin PVC. By 2020, only 9 percent of all post-consumer PVC waste in Europe is expected to be recycled, with a maximum potential of no more than 18 percent.

When the entire lifecycle of PVC is considered, it is apparent that PVC is one of the most environmentally hazardous materials in production. Vinyl production, use, and disposal is responsible for generating large quantities of persistent, bioaccumulative, and toxic pollutants—and then releasing them into the global environment. Available data suggest that PVC is a significant contributor to the world's burden of persistent organic pollutants and endocrine disrupting chemicals—including dioxins and phthalates—that have accumulated universally in the environment and the bodies of the human population.

These hazards are largely unique to PVC, which is the only major building material and the only major plastic that contains chlorine or requires phthalate plasticizers and metal stabilizers. Vinyl is the antithesis of a green building material. Efforts to speed adoption of safer, viable substitute building materials can have significant, tangible benefits for human health and the environment.

1. INTRODUCTION

PURPOSE

The purpose of this report is to present information on the environmental and health hazards associated with the lifecycle of polyvinyl chloride plastic (PVC; commonly known as vinyl). This report is not intended as a complete review of all aspects of the PVC lifecycle; rather, the most important evidence indicating that PVC poses important hazards to health and the environment have been surveyed from a perspective consistent with the precautionary principle. Individual chapters on the manufacture, use and disposal of vinyl products discuss the formation, release, exposure, and health implications of hazardous substances during the manufacture, use, and disposal of vinyl products are considered, as well as energy consumption associated with PVC production. The final chapter presents background information on scientific and economic issues relevant to vinyl and persistent organic pollutants, including a detailed discussion of the environmental hazards of dioxin-like compounds and phthalate plasticizers, two particularly hazardous classes of substances associated with the vinyl lifecycle.

In the United States, building and construction applications account for an estimated 75 percent of all vinyl consumption.[1] In the European Union, 60 percent of vinyl is used in building and construction applications, with an additional 25 percent in appliances, electronics, and furniture,.[2] In this report, hazards specific to building and construction uses are highlighted whenever possible; however, many of the hazards of the vinyl lifecycle are general to all PVC uses and will be discussed in that context. Because many of the hazards associated with PVC are global in scale, this report takes an international perspective on vinyl markets and environmental impacts. Further, significant quantities of vinyl and vinyl products are imported, so decisions on building materials in the United States have implications for environmental quality and worker and community health wherever PVC is manufactured.

THE LIFECYCLE OF PVC

The PVC lifecycle is marked by three major stages—manufacture, use, and disposal (figure 1). Environmental hazards of vinyl production include the formation and release of toxic substances and the consumption of energy and resources in any and all of these steps.

Manufacture

PVC manufacture is comprised of five major steps—ethylene and chlorine gas production, feedstock production, polymerization, formulation or compounding, and molding.

1. *Ethylene and chlorine gas production*—ethylene gas (purified from petroleum or natural gas) and chlorine gas (synthesized from sea salt by high-energy electrolysis) are two basic materials for vinyl production.

2. *Feedstock production*—ethylene dichloride (EDC, also known as 1,2-dichloroethane) can be produced from chlorine and ethylene by chlorination or oxychlorination. In chlorination, ethylene and chlorine are combined to produce EDC. Hydrogen chloride formed as a by-product in this reaction is then combined with more ethylene to produce additional EDC in a process known as oxychlorination. EDC is then converted into vinyl chloride monomer (VCM; the chemical name of which is chloroethylene), by a reaction called pyrolysis.

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[1] Geiser 2000.
[2] European Commission 2000.

3. *Polymerization*—VCM molecules are linked together to yield polyvinyl chloride, typically a white powder.

4. *Formulation or compounding*—pure PVC is mixed with other chemicals—stabilizers, plasticizers, colorants, and the like —to yield a usable plastic with desired properties. In its pure form, PVC is not particularly useful: it is rigid and brittle, and it gradually catalyzes its own decomposition when exposed to ultraviolet light. For PVC to be made into useful products, additives must be mixed with the polymer to make it flexible, moldable, and long lasting.[3] PVC additives include a range of toxic compounds, but the most environmentally important of these are the phthalate plasticizers and metal-based stabilizers—lead, cadmium, organotins, zinc, and other compounds.

5. *Molding*—the formulated plastic is molded to produce the final product, such as a bottle, floor tile, or pipe.

Usage

The second major stage in the PVC lifecycle is the use of vinyl products. The duration of the product's useful life may be short (PVC packaging, with a lifetime measured in days or weeks) or moderate (PVC floor tiles or roofing materials, which have an average lifetime of 9 to 10 years).[4] Environmental hazards during this stage include the release of toxic substances into the indoor or outdoor environment from the vinyl product or during accidental combustion, especially where large quantities of PVC are used, such as vinyl roofing membranes or siding.

Disposal

Finally, after its useful life, the vinyl product is disposed of, typically in incinerators or landfills. Environmental impacts at this stage include the long-term persistence of vinyl products in land disposal facilities, the product being leached of hazardous substances, and the formation and release of unintended combustion by-products when vinyl is incinerated or processed in a secondary smelter for recycling metal products. Only a small portion of vinyl is recycled, a process that can lead to the dispersal of hazardous additives into the environment or a greater range of consumer products.

INTERNATIONAL ACTION ON PVC

In the fall of 2000, international negotiations were completed on the first legally binding instrument to address global contamination by persistent organic pollutants (POPs). [5] The agreement, which will require each nation to eliminate the production of POPs, represents a fundamental shift from the present control and disposal techniques used to manage chemicals. Although the treaty takes initial action on just 12 pollutants, it includes provisions for additional substances to be addressed in the future. Four of these pollutants are produced in significant quantities during the vinyl lifecycle (table 1).

Currently there is considerable international concern and activity to restrict PVC consumption for environmental reasons. In 1995, for example, the American Public Health Association adopted a consensus resolution that hospitals should "reduce or eliminate their use of PVC plastics" wherever feasible due to the global health and environmental impacts of the PVC lifecycle—dioxin generation in particular.[6] In a study of all major packaging materials for the Council of State Governments in the United States, the independent Tellus Institute found that PVC is the most environmentally damaging of all

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[3] Tukker et al. 1995.
[4] Schneider and Keenan 1997.
[5] United Nations Environment Programme 2000.
[6] APHA 1996.

plastics.[7] A lifecycle analysis by the Danish EPA found that the common plastics polyethylene, polypropylene, polystyrene, polyethylene terephthalate (PET), and ethylene-propylene diene synthetic rubber are all clearly preferable to PVC in terms of resource and energy consumption, accident risk, and occupational and environmental hazards, including chemical exposure.[8]

Almost all European Union nations have restrictions on uses of PVC. These restrictions address concerns about dioxin exposure, release of phthalate softeners, or the difficulty of recycling and waste disposal. Among the most far-reaching policies are those of Sweden, whose parliament voted in 1995 to gradually eliminate soft and rigid PVC. In 1996, Sweden called for a voluntary industry phase-out of all PVC production. In 1999, it adopted a bill that includes mandatory provisions to eliminate use of PVC with hazardous additives—including phthalates and lead—and to substitute PVC use with other materials wherever feasible. From 1994 to 1999, this program had reduced total PVC use in Sweden by 39 percent.[9]

Denmark established a national strategy to address the environmental hazards of PVC, including a tax on PVC of $0.30 U.S. per kilogram, a higher tax on phthalates, a prohibition on the incineration of PVC, and an order to substitute alternative materials for all non-recyclable PVC use. The German Environmental Protection Agency (UBA) has called for an end to the use of phthalates and the gradual phase-out all uses of flexible PVC.[10] Due to the concern for dioxin generation, UBA has also called for a ban on the use of PVC in applications susceptible to fire.[11] The policy in the Netherlands is to reduce the use of PVC in products that are not recycled and to eliminate the use of phthalate plasticizers and lead stabilizers in PVC. The European Union has begun an official process to review the environmental hazards of PVC and to establish appropriate policy measures to safeguard the environment.[12]

Not all action on PVC is restricted to Europe. India’s Ministry of the Environment and Forests has established rules that ban the incineration of PVC and other chlorinated plastics in medical waste incinerators. Singapore has informed the Secretariat of the Basel Convention on the transboundary movement of hazardous waste that it considers PVC-containing waste and PVC-coated cables to be hazardous waste that are therefore banned from import or export.[13]

Numerous local and regional governments have specific policies to avoid PVC in construction.[14] In Germany, 274 communities—including Berlin and Bonn—and six states have written policies to phase-out or restrict PVC. The Netherlands’ four largest cities—Amsterdam, Den Haag, Rotterdam, and Utrecht—have specifications to avoid PVC whenever possible in construction. Fifty-two cities in Spain have declared themselves “PVC-free,” with specific strategies to substitute safer alternatives for PVC construction materials. Basel, Switzerland, has guidelines for the use of environmentally friendly materials, listing PVC as environmentally harmful and a candidate for substitution whenever possible. In Austria, seven of nine states and a large number of municipalities have restrictions on PVC. The city of Linz has reportedly achieved an 85 percent PVC phase-out in public buildings, and the Vienna subway and Vienna Ost hospital were constructed without PVC.

Numerous major construction products have reduced or eliminated PVC entirely. In an effort to utilize green building practices, the Sydney 2000 Olympics established a commitment “to minimizing and

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[7] Tellus Institute 1992.
[8] Christaensen et al. 1990. PVC was not judged demonstrably inferior under certain criteria (such as energy use and accident potential during manufacture) to polyurethane, acrylonitrile-butadiene-styrene, and aluminum.
[9] KemI 2000; Greenpeace International 2000.
[10] European Commission 2000.
[11] UBA 1992.
[12] European Commission 2000.
[13] Greenpeace International 2000.
[14] Greenpeace International 2000.

ideally avoiding the use of chlorine-based products such as PCBs, PVC, and chlorine-bleached paper." [15] PVC use was eliminated or radically reduced in the construction of the hotel, Olympic village, stadium, and many other structures. Seville's guidelines for the 2004 Olympics specify that "we must avoid the use of PVC in construction, infrastructure, accessories and any other complements in Olympics facilities." [16] The headquarters for the Danish society of Engineers has been built without PVC, as has the new European headquarters for Nike in Hilversum. Many buildings in the United Kingdom, including the new Tate Gallery of Modern Art, have been designed and built to minimize or eliminate PVC use.[17]

Many private firms have also taken steps to restrict or substitute PVC products.[18] The Swedish construction firms HM and Svenska Bostder have announced that they are phasing out PVC use. In Japan, the electronics manufacturers AEG, Electrolux, Matsushita, Ricoh, Sharp, Sony-Europe, and Vorwerk have PVC phase-out policies. German Telekom, Nippon, and Sumitomo Electric Industry have policies to avoid PVC use in cable manufacture. The furniture and décor manufacturers and retailers Eco AB, EWE Kuechen (Austria), IKEA, and Innarps AB have policies to avoid PVC products. In transportation, nearly all of the world's major car manufacturers, including BMW, Daimler-Benz, Ford, General Motors, Honda, Nissan, Opel, Toyota, and Volkswagen AG have policies to reduce or eliminate the use of PVC in automobiles.

Particularly urgent and widespread action has focused on PVC toys, due to concern for exposure of children to phthalate plasticizers in flexible PVC. In the late 1990s, government ministries in Denmark and the Netherlands found that substantial quantities of phthalates are released from PVC into saliva from vinyl teethers and chew toys. As a result, these countries, along with ministries in Austria, Belgium, Finland, France, Germany, Greece, Italy, Norway, Spain, and Sweden, sought bans on the use of soft PVC in toys. In 1997, a number of European toy retailers and manufacturers suspended sales of PVC teething rings or announced plans to eliminate all vinyl from their toy lines. In late 1998, when a wave of publicity on the issue hit the U.S. press, Mattel, Toys-R-Us, and several other U.S. toy makers and retailers announced that they would stop selling certain vinyl toys.[19] Subsequently, the U.S. Consumer Product Safety Commission called on the toy industry to voluntarily stop making vinyl chewing toys that contained phthalates.[20] In 1999, the European Commission finalized an emergency ban on six phthalate plasticizers found in soft PVC toys. Although toys represent a small fraction of total PVC consumption, the trend away from vinyl use in toys is significant for the entire industry. As one plastics industry spokesman commented, "In the long run, the industry will go the way toys go."[21]

PVC AND CHLORINE CHEMISTRY

EDC, PVC, VCM, and the by-products formed during the vinyl lifecycle are members of a large class of problematic chemicals called organochlorines—organic (carbon-based) substances that also contain one or more atoms of chlorine. The debate over PVC takes place in the context of broader concern about the class of organochlorines—regarded by many as the most environmentally problematic class of synthetic substances.[22] PVC is the only major plastic used in buildings that contains chlorine. Chlorine-free plastics include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), acrylonitrile-butadiene-styrene (ABS) copolymer, ethylene vinyl acetate (EVA), and numerous others. Polyurethane, polycarbonate, and epoxy resins are chlorine-free plastics that are currently manufactured via the

[15] Quoted in Greenpeace International 2000.
[16] Quoted in Greenpeace International 2000.
[17] Greenpeace International 2000.
[18] Greenpeace International 2000.
[19] Warren 1998; *New York Times* 1998.
[20] Mayer 1998.
[21] Warren 1998.
[22] Thornton 2000; Collins 2001; International Joint Commission 1992; APHA 1994.

organochlorine intermediates chlorohydrin, epichlorohydrin, phosgene, and propylene, but technologies are being developed to produce these plastics through chlorine-free routes.[23]

The proper course of action for addressing organochlorines is controversial. Some organizations and analysts, including the American Public Health Association and the International Joint Commission (a binational advisory body of the United States and Canadian governments charged with protection of the Great Lakes ecosystem), have called for a gradual phase-out of all uses of chlorine and organochlorines. Others, including the chemical industry and the Society of Toxicologists, have advocated continuing the current system of chemical-by-chemical regulation.[24]

Decisions about the use of PVC in building materials do not require the proper course of action on all organochlorines to be resolved. The question of vinyl should be seen, however, in the context of concern about the class of chemicals of which PVC is perhaps the most important member. Vinyl and its feedstocks have the largest production volume, by far, of all organochlorines. Further, a vast variety of other organochlorines are produced in considerable quantities during the lifecycle of vinyl. Many of these by-products are known to be hazardous; many more have not been specifically identified or evaluated for their environmental behavior and toxicity, and an understanding of the general characteristics of organochlorines is relevant to predicting their hazards.

Concern about organochlorines began with the recognition that they tend to dominate all major lists of "priority pollutants." For example, of the 12 POPs addressed by United Nations Environmental Programme (UNEP), all are organochlorines, and four are produced by the PVC lifecycle (see table 1). Of the 11 chemicals on the International Joint Commission's Critical Track of hazardous pollutants in the Great Lakes, eight are organochlorines, as are 168 of the 362 Great Lakes contaminants on the IJC's Secondary Track.[25] Organochlorines are prominent on EPA's list of common groundwater pollutants and of contaminants at hazardous waste sites, and they constitute the majority of the list of known endocrine disrupting chemicals.[26]

Further analysis has revealed why organochlorines are so problematic. Organochlorines tend to have several characteristics, all of which derive from fundamental chemical properties of the chlorine atom. The same properties that make chlorine and organochlorines useful in industrial applications, in fact, are responsible for their environmental hazards.

Reactivity of chlorine. Chlorine gas is extremely reactive, combining quickly and randomly with any organic matter it contacts. This property makes it an effective bleach, disinfectant, and chemical feedstock, but also results in the generation of a diverse mixture of by-products, typically containing hundreds or thousands of organochlorines—including dioxins—whenever chlorine is used.[27]

Persistence. The chlorine atom is extremely electronegative, which means it exerts a strong pull on the electrons it shares with carbon atoms in an organochlorine—significantly stronger than the hydrogen atom it usually replaces. The addition of chlorine to organic molecules therefore changes the chemical stability of the resulting substance—often stabilizing but sometimes destabilizing it, depending on the structure of the parent compound. In most cases, the resulting organochlorine is far less reactive than the original substance; organochlorines that do break down usually degrade into other organochlorines, which may be more persistent and toxic than the original substance. Stability makes organochlorines useful as plastics, solvents, and refrigerants—applications for which long-life and fire-resistance are virtues. This

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[23] For a discussion of chlorine-free synthesis technologies, see discussion and references in Thornton 2000.
[24] Karol 1995.
[25] Great Lakes Water Quality Board 1987.
[26] Burmaster and Harris 1982; Miller et al. 1991; Guillette and Crain 1999.
[27] See discussion and references in Thornton 2000.

same property, however, makes these organochlorines persistent in the environment and therefore likely to accumulate and become globally distributed.

In some cases, organochlorines become more unstable and reactive than the parent compound, making them useful as chemical intermediates. But this property also makes them more easily converted in the body to toxic and reactive metabolites (other organochlorines), which can then proceed to damage DNA or other essential molecules in cells.[28] Chlorine's impact on the stability of organic molecules thus has one of two opposite effects, depending on the structure of the parent compound—and both are problematic from an environmental health perspective.

Bioaccumulation. One factor that determines the solubility of a substance in water or fat is its molecular size: the larger a molecule, the more it disrupts interactions among water molecules and the greater the tendency for the substances to be nondissolvable in water. The chlorine atom is very large—several times larger than an atom of carbon, hydrogen, or oxygen—so chlorination significantly increases the size of organic molecules and as a result almost invariably increases solubility in fats and oils. The increase in fat solubility applies to the chlorination of virtually any organic substance, and increases with each chlorine atom added.[29] Thus, for example, tetrachloroethylene, hexachlorobenzene and octachlorodibenzofuran, are about one hundred, one thousand, and one billion times more oil-soluble, respectively, than their chlorine-free analogs (figure 2). Oil-solubility makes organochlorines useful as solvents and dielectric fluids, but it is directly responsible for the tendency to bioaccumulate.

Toxicity. Organochlorines tend to be overwhelmingly toxic. The American Public Health Association has concluded that "virtually all organochlorines that have been studied exhibit at least one of a range of serious toxic effects, such as endocrine dysfunction, developmental impairment, birth defects, reproductive dysfunction and infertility, immunosuppression and cancer, often at extremely low doses, and many chlorinated organic compounds…are recognized as significant workplace hazards."[30] According to a comprehensive independent review of thousands of individual organochlorines, chlorination of organic chemicals "is almost always associated with an increase in the toxic potential. Only rarely does chlorination produce no increase or even a decrease in effects. This observation applies for all kinds of toxic effect (acute, subchronic, and chronic toxicity; reproductive toxicity; mutagenicity; and carcinogenicity)."[31] The general toxicity of organochlorines makes them useful as pesticides and antibiotics, but also hazardous to humans and wildlife once they enter the environment.

[28] Henschler 1994.
[29] Solomon et al. 1993.
[30] APHA 1994.
[31] Henschler 1994.

Figure 1 Lifecycle of PVC

Stages are shown in boxes with bold and regular type. Arrows show material flows.

Table 1 Persistent organic pollutants addressed by UNEP's International POPs Agreement

Pollutant
Aldrin
DDT
Dieldrin
Endrin
Chlordane
Heptachlor
* Hexachlorobenzene (HCB)
Mirex
Toxaphene
* Polychlorinated Biphenyls (PCBs)
* Polychlorinated dibenzo-p-dioxins (PCDDs)
* Polychlorinated dibenzo-furans (PCDFs)

* Produced at one or more points during the lifecycle of PVC.
Source: UNEP 1997.

Figure 2 Effect of chlorine on oil-solubility and bioaccumulation of organic chemicals

In all groups, chlorination increases the tendency of a chemical to dissolve in fats and oils, and each chlorine atom has a greater effect. Blank cells indicate no data available.

Source: HSDB 1997.

2. PVC PRODUCTION

PRODUCTION OF CHLORINE

The PVC lifecycle begins with the production of chlorine gas in the chlor-alkali process. Electricity is passed through a solution of brine to produce sodium hydroxide (also called alkali or caustic soda) and chlorine gas in a fixed ratio of 1.1 to 1. Because chlorine gas and sodium hydroxide react with each other on contact, the key to the process is to separate immediately the chlorine from the alkali in a specially designed electrolytic chamber, called a cell. There are three types of chlor-alkali cells in use, which differ in the ways that chlorine and alkali are separated from each other.

The mercury process, the oldest and most energy-intensive of the three processes for chlorine production, involves two connected cells. In the first cell, salt is split into chlorine gas and sodium at the cell's positive terminal (called the anode); the sodium forms an amalgam with a layer of liquid mercury, which then flows into another cell, where it reacts with water to form sodium hydroxide and hydrogen gas. The mercury process is banned in Japan, but 35.5 percent of chlorine production worldwide is by this method, with 14 percent of chlorine in North America and 65 percent of that in Western Europe produced by this technology as of 1994. In Western Europe, the Oslo-Paris Commission on the Northeast Atlantic has recommended that mercury cells be phased out, so the proportion of mercury-related chlorine is expected to decline.[32]

In the asbestos diaphragm process, brine enters the cell and is split at the anode, yielding chlorine gas and sodium ions. The ions then flow through a semi-permeable asbestos barrier to the other pole, where they react with water to form sodium hydroxide and hydrogen gas. Chlorine, which cannot pass through the membrane, remains near the anode. The diaphragm method was developed after the mercury process and, as of 1994, accounted for 77 percent of all chlorine production in the United States and 25 percent in Europe.[33]

The remaining 7 percent of chlor-alkali production is based on the membrane process, the most recently developed of the three methods. The membrane technique is similar to the diaphragm process, except that a synthetic membrane rather than asbestos is used to separate the compartments in which chlorine and alkali are formed. The membrane process uses slightly less energy and yields products of higher purity than the other kinds of cell, but retrofitting a chlorine plant with membranes is expensive. Because most chlor-alkali plants in the United States and Europe were built decades ago, few use the membrane process. But most new facilities—particularly those in Asia and Latin America—are now constructed with it.[34]

The world chlor-alkali industry produced nearly 39 million metric tons of chlorine in 1997; 27 percent of that was made in the United States. There are 42 chlor-alkali facilities in the United States, but more than 70 percent of production capacity is located at just 12 large plants in the Gulf Coast region of Louisiana and Texas.[35] Because vinyl accounts for more than 40 percent of all chlorine consumption, it is reasonable to estimate that the same proportion of the environmental impacts of chlorine production—releases of toxic substances and energy demand—is associated with the vinyl lifecycle.

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[32] Leder et al. 1994

[33] Leder et al. 1994.

[34] Leder et al. 1994.

[35] Leder et al. 1994; see also Thornton 2000.

Organic by-products

From the moment that chlorine gas is formed in the chlor-alkali cell, it will react with any organic matter present to form organochlorines. For this reason, manufacturers purify raw materials and equipment surfaces carefully to remove as much organic material as possible. Nevertheless, carbon-containing substances remain as trace impurities—in plastic materials or from the graphite electrodes used in some types of chlor-alkali cells.[36] Chlorine combines with these organic contaminants to form persistent organochlorine by-products, such as HCB and hexachloroethane (HCE), which are found in the chlorine product itself.[37] Chlorine gas can also be contaminated with PCBs, OCS, and tetrachlorobenzene. The concentrations are moderate—40 to 210 parts per billion (ppb)[38]—but the quantities are significant: based on the levels found, the chlorine gas produced each year carries between 1.6 and 8.2 tons of these highly persistent and toxic by-products into the world's economy.[39] Based on an attributable fraction of 40 percent, the chlorine used for vinyl contains between 1,400 and 7,200 pounds of these substances annually.

Much greater quantities of organochlorine contaminants are deposited in chlorine production wastes. Swedish researchers have identified high concentrations of dioxins and furans[40] in the sludges from spent graphite electrodes used in chlor-alkali cells,[41] and high levels of polychlorinated dibenzofurans have been found in the blood of Swedish chlor-alkali workers.[42] The levels were up to 650 ppb, with TEQ values up to 28 ppb. (Because dioxin-like compounds cause toxicity through a common mechanism, mixtures of these substances can be expressed relative to the toxicity of TCDD, the most toxic dioxin, as TCDD-equivalents (TEQ). To calculate the TEQ value for a mixture, the quantity of each substance is multiplied by its toxicological potency relative to TCDD, and the TEQ is the sum of these weighted quantities. A mixture with a calculated TEQ of 1 microgram is expected to have toxicity equal to 1 microgram of TCDD.)

Severe contamination of fish and sediments with OCS—an extremely persistent, bioaccumulative POP—has been documented near eight North American chlorine producers. Additionally, large-scale OCS contamination of sediments in Lake Ontario has been traced to disposal of spent chlor-alkali electrodes.[43] OCS is now a global contaminant, with considerable levels found in the Canadian arctic—and chlor-alkali manufacture is considered an important source of that contamination.[44]

As a result of these problems, all chlor-alkali plants in North America and many in Europe replaced graphite electrodes with titanium substitutes during the 1970s and 1980s—a move that industry and government assumed eliminated the formation of organochlorine by-products. But recent data indicate that even the most modern chlor-alkali plants produce dioxin-like compounds. With graphite eliminated, traces of organic chemicals are still present, primarily from plastic pipes and valves that release small quantities of their materials into the cell. A 1993 study by Swedish scientists found dioxins

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36 Schmittinger et al. 1986.

37 HSDB 1997.

38 Hutzinger and Fiedler 1988.

39 My calculation of annual loadings assumes world production of 39 million metric tons of chlorine each year (Leder et al. 1994).

40 Polychlorinated dibenzofurans (PCDFs, or furans) are structurally related to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, known colloquially as dioxin), the best studied and most hazardous of the dioxin-like compounds, a large group of structurally and toxicologically related group of compounds that includes not only the furans but also some PCBs, chloronaphthalenes, and many others), together referred to as dioxins or dioxin-like compounds.

41 Rappe et al. 1991

42 Svennson et al. 1993.

43 Kaminski and Hites 1984.

44 Barrie et al. 1997.

and furans in the sludge and plastic piping from a modern chlor-alkali plant with titanium electrodes at levels near 5 ppt (TEQ).[45] Subsequent Swedish research found significant quantities of chlorinated dibenzofurans in the sludge from a chlor-alkali plant with titanium electrodes, apparently due to chlorination of organic compounds in the rubber linings of the cell.[46] In 1997, the UK Environment Agency confirmed that a chlor-alkali plant owned by ICI Chemicals and Polymers, which replaced its graphite electrodes around 1980, continues to release dioxins in its wastewater.[47]

Mercury releases

Most of the mercury used in mercury chlor-alkali cells is recycled, but significant quantities are routinely released into the environment via air, water, products, and waste sludges. In the 20th century as a whole, chlor-alkali production has been the largest single source of mercury releases into the environment.[48] As recently as the 1980s, the chlorine industry was second only to fossil fuel combustion as a mercury source in Europe.[49]

Many mercury-cell plants have been retired in the past two decades, and controls on existing plants have improved, but chlor-alkali facilities remain a source of mercury pollution. The chlorine industry is the largest mercury consumer in the United States; it is presumably even more important in Europe, where the mercury cell process is more common.[50] According to the Chlorine Institute (an industry organization) the chlor-alkali industry in the United States consumes 176,769 pounds of mercury per year.[51] By definition, materials consumed are by definition not recycled but are released directly to the environment, into wastes, or in the product itself. Without providing documentation, the Vinyl Institute has argued that only 20 percent of the chlorine produced by the mercury process in the United States is used to produce PVC.[52] Based on these two figures, vinyl manufacture in the United States alone is associated with the release of more than 35,000 pounds (about 16 metric tons) of mercury into the environment each year.

The U.S. industry's figures probably significantly underestimate actual mercury releases. More detailed estimates, derived by superior mass-balance accounting methods, are available based on studies conducted by Euro-Chlor, the trade association of the European chlorine industry.[53] This information indicates that the world chlor-alkali industry consumed about 230 tons of mercury in 1994; this is the quantity not recycled but lost from production processes each year. Exactly where the mercury goes remains controversial, but if we extrapolate from the Euro-Chlor estimates, about 30 tons were released directly into the air and water, 5 tons remained as a contaminant in the product, more than 150 tons were

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[45] Andersson et al. 1993.
[46] This research is summarized in Versar, Inc. 1996 and EPA 1998.
[47] Environment Agency 1997.
[48] Lindqvist et al. 1991.
[49] Lindqvist et al. 1991; Pacyna and Munch 1991.
[50] Ayres 1997.
[51] Chlorine Institute 2000.
[52] Burns 2000.
[53] The data from Euro-Chlor, presented in Ayres 1997, are the most comprehensive available. The data are based on a mass balance method, so that all mercury consumed is accounted for in one way or another. My calculation of total mercury releases from the chlor-alkali industry uses this range and assumes 39 million tons global chlorine production,35.5 percent through the mercury process (Leder et al. 1994). The actual total may be higher, since many plants are not likely to be as well operated as those in Europe. Euro-Chlor's estimates of releases to water and air (0.2 and 1.9 grams of mercury per ton of chlorine, respectively) are somewhat lower than estimates made by other parties. One review estimates mercury releases at 3 grams per ton of chlorine for a new chlor-alkali plant, and 10 grams per ton of chlorine for a well-operated existing facility (Schmittinger et al. 1986). Real-world plants in Germany have been found to release 19 grams per ton (SRI International 1993).

disposed on land, and 36 tons could not be accounted for (table 2). Based on these figures and an attributable fraction of 40 percent, the PVC lifecycle is associated with the consumption of 92 metric tons of mercury (202,400 pounds) per year, of which the majority is released into air, water, or landfills. If we use the Vinyl Institute's U.S.-based estimate that 20 percent of the chlorine produced by the mercury process is used to produce PVC, production of chlorine for vinyl would account for the release of 46 tons per year of mercury each year. The actual worldwide totals are likely to be even higher since the well-regulated facilities of Europe are not likely to be representative of those in other regions of the world.

Mercury is an extremely toxic, bioaccumulative global pollutant. Mercury compounds cause irreversible health damage to wildlife and humans—especially to developing children, resulting in birth defects, impaired neurological development, kidney damage, and severe neurological destruction.[54] The most tragic and infamous example of mercury pollution happened in Minimata, Japan, where the Chisso Chemical company routinely dumped mercury-contaminated waste into the local bay from the 1930s to the 1960s. Fish in Minimata Bay bioaccumulated mercury to levels 40 to 60 times higher than those in nearby ecosystems, and the local population—among whom a diet of fish played a key role—suffered high mercury exposures. In the early 1950s, symptoms of chronic mercury poisoning, including neurological toxicity, paralysis, coma, and death began to appear in adults in the community, and a horrifying outbreak of severe birth defects and mental retardation occurred in children. Ultimately, mercury poisoning killed hundreds and injured more than 20,000 people in the Minimata area.[55] Chlor-alkali production is not traditionally assumed to have been the source of the Chisso's mercury releases because the company had been using mercury as a catalyst in fertilizer production since the 1930s. As one history of the event points out, however, Chisso began using the mercury process to make chlorine for PVC plastic in 1952. In 1953, symptoms of mercury poisoning began to appear in the local population, and over the next four years the number of victims correlated with Chisso's growing production volume of vinyl chloride.[56] This pattern suggests that mercury releases from the chlor-alkali process are likely to have played a role in the Minimata epidemic.

Today, mercury exposure remains a major environmental health problem. According to a recent report by the U.S. National Academy of Science, "Individuals with high [mercury] exposure from frequent fish consumption might have little or no margin of safety—in other words, exposures of high-end consumers are close to those with observable adverse effects. Those most at risk are children of women who consumed large amounts of fish and seafood during pregnancy. The committee concludes that the risk to that population is likely to be sufficient to result in an increase in the number of children who struggle to keep up in school and who might require remedial classes or special education."[57]

Mercury cells are now banned in Japan and are gradually being phased out in the United States and Europe as well, but releases of mercury remain a problem. In the 1980s, for instance, a major British chlor-alkali facility was found to be discharging up to 100 kilograms per day of mercury into local waterways; more than a decade later, mercury levels in the sediment remained extremely high.[58] In Italy, elevated levels of mercury in air, soil, and plant tissues have been found in the vicinity of a mercury-based chlor-alkali plant owned by the Solvay Company.[59] In India, a 1990 study of waterways around a chlorine facility documented severe mercury contamination of fish and sediments.[60]

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[54] ATSDR 1998.
[55] Harada 1995; Davies 1991.
[56] Hill and Holman 1989.
[57] National Academy of Sciences 2000.
[58] Airey and Jones 1970; Johnston et al. 1993.
[59] Maserti and Ferrara 1991.
[60] Panda et al. 1990.

Energy consumption

Chlorine production requires enormous amounts of energy. Chlor-alkali electrolysis is one of the most energy-intensive industrial processes in the world. The production of one ton of chlorine requires about 3,000 kilowatt-hours of electricity, and the global chlor-alkali industry consumes about 117 billion kilowatt-hours of electricity each year.[61] This quantity is about 1 percent of the world's total demand for electricity,[62] costs about $5 billion per year,[63] and is equivalent to the annual power production of about 20 medium-sized nuclear power plants.[64] As a major energy consumer, chlorine chemistry contributes considerably to all the environmental problems—global warming, air pollution, acid rain, mercury emissions, generation of radioactive and other wastes from the mining, processing, and consumption of nuclear fuels, and so on—that are associated with energy production.

Based on an attributable fraction of 40 percent of chlorine demand, the chlorine consumed in vinyl production is associated with electricity consumption of approximately 47 billion kilowatt-hours per year. On a per mass basis, production of chlorine to make one ton of PVC consumes about 1,800 kilowatt-hours of electricity, based on the fact that pure PVC is 59 percent chlorine by weight. Additional energy is consumed in the chemical synthesis of EDC, VCM, and PVC and in the production of additives in the vinyl product. An estimate of the total energy consumption required for the manufacture of PVC is beyond the scope of this document.

SYNTHESIS OF EDC AND VCM

Releases of EDC and VCM

Large quantities of EDC and VCM are released directly into the environment during the production of feedstocks for PVC. Because at least 95 percent of the world's annual production of 24 million tons of VCM goes into PVC, these releases are almost entirely attributable to vinyl products.

Undoubtedly, extremely large quantities of EDC and VCM are released into the air and water each year. As part of the U.S. Toxics Release Inventory (TRI), manufacturers of PVC and its feedstocks self-reported emissions of 887,000 and 798,000 pounds of VCM and EDC, respectively, directly into the environment in 1998; an additional 2 million pounds of VCM and 27 million pounds of EDC were reported sent to sewage treatment plants or off-site waste facilities.[65] These figures may significantly underestimate actual releases, however, because of widely recognized problems with the TRI database. Reported emissions are not based on actual monitoring of releases, and estimation methods vary greatly among facilities. Most importantly, TRI release estimates are self-reported by the industry and are thereby subject to no independent verification.

More valid figures come from estimates made by the Norwegian government in 1993. Based on a detailed mass balance conducted at a Norwegian facility, specific estimates of per-ton releases of EDC

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[61] Energy requirements vary somewhat among the chlor-alkali cell types: the mercury cell requires 3310-3520 kilowatt-hours per ton of chlorine, the diaphragm 2,830 kilowatt-hours per ton, and the membrane process 2,520 kilowatt-hours per ton. Based on the proportion of each cell type in the world industry, the average energy requirement for the industry overall is slightly under 3,000 kilowatt-hours per ton (SRI International 1993).

[62] SRI International 1993.

[63] Assuming an average global cost of 4.2 cents per kilowatt-hour for chlor-alkali customers (SRI International 1993).

[64] In the United States, 109 nuclear plants generated 673 billion kilowatt-hours of electricity, for an average of about 6 billion kilowatt-hours per plant per year (Energy Information Administration 1996).

[65] National Institutes of Health 1998.

and VCM from vinyl manufacture were made (table 3). Extrapolating these estimates using 1990 vinyl production figures,[66] we can calculate that the PVC industry releases at least 100,000 tons each of EDC and VCM into the air each year—plus more than 200 tons of EDC and 20 tons of VCM into surface water. Worldwide VCM production has increased by about 50 percent in the past decade,[67] which increases the associated estimates of total releases by a similar fraction. The actual total may be even higher since this estimate was extrapolated from emissions at a single facility in Norway: manufacturers in many other nations have less advanced pollution control equipment and less careful plant operation than this relatively modern, well-regulated facility.

EDC and VCM are not particularly persistent—but both are highly toxic. Releases of these compounds therefore pose the greatest hazards for communities and ecosystems near EDC/VCM manufacturing facilities. The facility studied in Norway, for instance, releases 40 to 100 tons of EDC each year directly into the local atmosphere.[68] In the United States, some 12.5 million people are exposed to EDC emissions from chemical manufacturing facilities, according to the National Institute for Occupational Safety and Health. Workers in plants that manufacture PVC or its feedstocks receive the highest exposures to these compounds in workplace air—81,000 U.S. workers are regularly exposed to vinyl chloride, while 77,000 are exposed to EDC.[69]

According to the International Agency for Research on Cancer and the U.S. National Toxicology Program, VCM is a known human carcinogen, and EDC is a probable human carcinogen. Studies of workers exposed to VCM have shown an unambiguous increase in liver cancer. Four out of five studies also report an increased risk of brain cancer that is statistically significant in a combined analysis.[70] Both EDC and VCM cause a variety of other toxic effects, including immune suppression, liver damage, neurological toxicity, and testicular damage.[71]

Since the carcinogenicity of VCM was established, government regulations have required considerable reductions in worker VCM exposure. In the United States, workplace VCM levels within the 1–5 ppb range are now required—orders of magnitude lower than typical concentrations of the 1950s and 1960s—but much higher levels continue to occur in facilities elsewhere.[72] For example, a recent survey found that workers in Asia and Eastern Europe are typically exposed to VCM at levels up to 1,000 times the typical U.S. concentrations. In China, the air in dormitories for plastics industry workers and their families contains VCM levels that exceed the permissible workplace level in the United States.[73]

Although occupational exposure to EDC and VCM has declined significantly in the United States, even the much lower levels that now characterize the domestic vinyl industry remain a matter of concern, because there appears to be no safe dose of these compounds. The mechanisms by which EDC and VCM cause cancer have been elucidated, and it is now clear that both substances are genotoxic—causing irreversible damage to DNA. Indeed, VCM has been shown to form chemical bonds with DNA, leading to mutations that abolish natural controls over cell differentiation and proliferation.[74] Currently accepted biological theory indicates that mutations in a single cell can result in the development of a malignant tumor; similarly, a single molecule of a genotoxic substance can damage DNA. Carcinogens such as VCM therefore are not likely to have a threshold below which they do not increase the risk of

[66] Production estimates are 29,137 kilotons EDC per year, 18,495 kilotons of VCM per year, and 18,135 kilotons of PVC per year (SRI International 1993).
[67] Kielhorn et al. 2000.
[68] SFT 1993.
[69] ATSDR 1993; ATSDR 1995.
[70] Kielhorn et al. 2000.
[71] ATSDR 1993; ATSDR 1995.
[72] Kielhorn et al. 2000.
[73] Kielhorn et al. 2000.
[74] Kielhorn et al. 2000.

cancer. That is, any exposure to this carcinogen poses some risk of cancer, and the magnitude of the risk increases with the level of exposure.[75] The same is true of other health impacts mediated by DNA damage, including certain birth defects and genetic diseases. Thus, reduced levels of EDC and VCM in U.S. PVC production facilities reduce but do not eliminate the occupational health risks from these chemicals.

The health effects of community EDC and VCM exposure remain largely unstudied. It is clear, however, that severe environmental contamination and social disruption have occurred in several communities near EDC and VCM production facilities. As an example, Reveilletown, Louisiana, was once a small African-American community adjacent to a EDC/VCM facility owned by Georgia-Gulf. In the 1980s, after a plume of vinyl chloride in groundwater began to seep under homes in the area, a number of residents complained of health problems and brought a lawsuit against the company. In 1988, Georgia-Gulf agreed to an out-of-court settlement that provided for the permanent evacuation of the community but sealed the court records and imposed a gag order on the plaintiffs. One hundred six residents were relocated and Reveilletown has since been demolished.[76]

The next year, as concern about air and groundwater pollution grew around Dow Chemical's EDC/VCM facility five miles from Reveilletown in the small town of Morrisonville, near Plaquemine, Louisiana, Dow began to buy out and relocate citizens there in a pro-active program to avoid exposure, liability, and bad press. Morrisonville, too, is now all but abandoned.[77] On the other side of the state, in Lake Charles, Louisiana, PPG and Vista Chemical manufacture EDC and VCM, which, along with by-products of their synthesis, now contaminate water and sediments in the Calcasieu Estuary.[78] Residents here continue to occupy their homes, drink local water, and eat fish from the area's polluted bayous. Because many EDC/VCM manufacturing facilities are located in communities with poor and/or minority populations, this stage of the PVC lifecycle has considerable environmental justice impacts.

Formation of organochlorine by-products

EDC/VCM synthesis generates large quantities of persistent, bioaccumulative by-products. EDC is made in two ways: ethylene is chlorinated with chlorine gas, or ethylene is oxychlorinated with hydrogen chloride that has been formed as a waste in other synthesis processes. Most EDC producers use both methods in a linked cycle, since chlorination of ethylene generates hydrogen chloride as a by-product, which can then be used in oxychlorination. Both processes yield a complex mixture of reaction products, which are then distilled to yield three batches of materials: the distilled EDC product, the light ends (those substances more volatile than EDC), and the heavy ends (less volatile than EDC). The waste quantities are quite large—about two kilograms each of heavy and light ends for each ton of EDC produced. Based on these figures, world EDC synthesis by the oxychlorination process produces at least 30,000 tons per year each of light and heavy ends.[79]

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[75] Pitot and Dragan 1991.
[76] Bowermaster 1993.
[77] Bowermaster 1993.
[78] Curry et al. 1996.
[79] My calculations assume that about 15 million metric tons per year of EDC produced by oxychlorination (half of world production (SRI International 1993), assuming integrated oxychlorination and direct chlorination process in 1.1 molar ratios). Heavy and light ends are assumed to be produced at the rate of 2 kilograms each per ton, based on the fact that production of 168,796 tons of EDC in Sweden per year results in the generation of 335 and 333 tons per year of heavy and light ends, respectively (TNO Centre for Technology and Policy Studies 1996). This figure is slightly lower than that of Rossberg et al. (1986), who estimate 2.3 and 2.9 kilogram heavy and light ends per ton of VCM produced, respectively. Use of more recent figures for global PVC production rates (Kielhorn et al. 2000) increases this estimate by about 50 percent.

In general, the heavy ends are discarded and the light ends reprocessed in other chemical reactions. EDC goes on to be pyrolyzed—heated in the absence of oxygen—to yield VCM. By-products formed in this process include chlorinated ethanes, chlorobenzene, chlorobutadiene, ethylenes, methanes, and large amounts of complex but uncharacterized waste tars.[80] According to industry sources, the total amount of chemical wastes produced in the various processes involved in EDC/VCM synthesis is estimated as between 3 to 10 percent of the VCM yield—a staggering 570,000 to 1.9 million tons of by-products each year.[81]

The heavy ends contain most of the persistent and toxic by-products. No academic or government studies have sought to identify all the compounds present in these wastes, but there are data from industry and environmental groups. In 1990, Dow Chemical analyzed its EDC heavy ends and found them to be about 65 percent chlorine, including large quantities of highly persistent, bioaccumulative, and toxic substances: 302 ppm PCBs, 0.3 percent HCE, 1.2 percent hexachlorobutadiene (HCBD), and 30.6 percent unidentified compounds.[82] If Dow's analysis is representative of heavy ends in general, then EDC oxychlorination results in the worldwide production of a remarkable 20,000 pounds of PCBs each year, even though these compounds were banned from intentional production some 20 years ago.[83]

The vinyl industry claims that these by-products are "contained" within the production equipment and thereby never released into the environment. But releases and contamination have clearly occurred. In 1993, chemists from the Greenpeace laboratory at the University of Exeter analyzed material from a number of European EDC/VCM manufacturers. Soil and gravel samples taken near a Swedish oxychlorination reactor contained a wide variety of persistent organochlorines in the high ppm range, and HCB and HCBD were present at the remarkable levels of 1.9 and 0.6 percent by weight.[84] The following year, Greenpeace obtained samples of heavy ends from several U.S. EDC/VCM manufacturers and had them analyzed by the Exeter laboratory. In one sample from Borden Chemical, 174 organochlorines were identified, including a wide variety of highly chlorinated substances with a range of chemical structures, many of them highly persistent, bioaccumulative, and toxic.[85]

Formation of dioxins

With PCBs and HCB in the wastes from PVC production, it is no surprise that the structurally related and extremely hazardous dioxins and furans are found in significant quantities, as well. Dioxins have been detected in the wastes from VCM synthesis. In research at a chemical plant in Russia, substantial quantities of dioxins and furans were identified in the wastewater and wastewater sludge from the pyrolytic production of VCM from EDC—as well as in the waste incinerator emissions.[86] But the largest quantities of dioxin are formed in the production of EDC by oxychlorination. As the British chemical company ICI made clear in a submission to the government, the formation of dioxin in this process is inevitable and unpreventable:

> It has been known since the publication of a paper in 1989 that these oxychlorination reactions generate polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs).

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[80] Rossberg et al. 1986.

[81] The lower estimate is from Papp 1996. The upper estimate is from Rossberg et al. 1986, assuming synthesis of EDC in integrated chlorination/oxychlorination facility plus pyrolysis to VCM, and includes releases to air, water, heavy ends, and light ends, except nitrogen gas vented to the atmosphere and aqueous streams.

[82] Dow Chemical 1990.

[83] This calculation assumes global production of 32 kiltons of EDC heavy ends per year, as discussed in the section above. Use of more recent figures for global PVC production rates (Kielhorn et al. 2000) would increase this estimate by about 50 percent.

[84] Johnston et al. 1993.

[85] Costner et al. 1995.

[86] Khizbullia et al. 1998.

> The reactions include all of the ingredients and conditions necessary to form PCDD/PCDFs, i.e., air or oxygen, a hydrocarbon (ethylene, etc.), chlorine or hydrogen chloride, a copper catalyst, an ideal temperature, and an adequate residence time. It is difficult to see how any of these conditions could be modified so as to prevent PCDD/PCDF formation without seriously impairing the reaction for which the process is designed.[87]

The 1989 paper to which ICI was referring was the work of a group of chemists at the University of Amsterdam who simulated the oxychlorination process in the laboratory and found dioxin formation at a rate that would make this method of producing EDC one of the world's largest—if not the largest—sources of dioxin.[88] These authors estimated that 419 grams of dioxin TEQ are formed per 100,000 tons of EDC produced—a rate equivalent to more than 60,000 grams of dioxin (TEQ) per year from the world vinyl industry.[89] Although not all the dioxins created would be released directly into the environment, this quantity is more than 50 times the annual dioxin emissions from all trash incinerators in the United States—the largest known source of U.S. dioxin emissions. It is also double the 25,000 grams of dioxin (TEQ) per year that EPA estimates are carried into the environment by contaminated pentachlorophenol[90]—the largest identified source of dioxin to any environmental medium.

This research generated considerable public and scientific concern. As a result, the vinyl industry began its own sampling program. In 1993, the Norwegian PVC manufacturer Norsk-Hydro confirmed that its EDC/VCM synthesis plant produced dioxins but claimed the quantities were hundreds of times lower than the Dutch study had predicted.[91] How much dioxin is actually formed remains uncertain, because both studies have strengths and weaknesses. On one hand, the Dutch analysis may be a more accurate indicator of total dioxin generation because the researchers captured and analyzed all the material outputs from the oxychlorination process. The Norwegian report, like any study of a full-scale facility, inevitably missed some of the by-products, which are directed into too many different equipment surfaces, products, recirculating materials, and wastes to be completely assessed in a large-scale industrial context. On the other hand, the Dutch study was a laboratory simulation, and the industry analysis took place at a real production facility; there may be reasons why the simulation caused more dioxin to form than a real-world synthesis of EDC.

Whatever the exact quantities, there can be no doubt that dioxin generation occurs in far from negligible amounts. In 1994, government scientists found dioxins at high concentrations (up to 414 ppb TEQ) in sludges from a fully modernized EDC/VCM plant in Germany, refuting the claim that only outdated EDC/VCM technologies produce dioxin.[92] The same year, ICI Chemicals and Polymers found that its vinyl chloride plant in Runcorn, UK, was producing large quantities of dioxin—not as much as the Dutch studies predicted but substantially more than Norsk-Hydro had estimated. Most of the dioxins at ICI were deposited in heavy-end wastes, and smaller quantities were released directly into the air and water.[93]

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[87] ICI Chemicals and Polymers 1994.
[88] Evers 1989.
[89] Based on early 1990s world production of EDC by oxychlorination of about 15 million tons per year (see note above).
[90] EPA 1998.
[91] The conclusions from this study are summarized in SFT 1993.
[92] Lower Saxony Ministry of Environmental Affairs 1994.
[93] Total dioxin generation associated with EDC/VCM synthesis was estimated at 27 grams (TEQ) per 200,000 tons of VCM, for a dioxin generation rate of 13.5 grams (TEQ) per 100,000 tons—substantially more than the Norwegian estimate but less than the Dutch figure. If production at the same plant of perc and trichloroethylene from the heavy ends of EDC oxychlorination are included, the estimate of dioxin formation increases to 500 grams TEQ per year from this plant alone. Based on this estimate, all oxychlorination processes would constitute one of the world's largest sources of dioxin (Environment Agency 1997).

In the United States, wastes from Vulcan Chemical's EDC plant in Louisiana have been found to contain dioxins and furans at the concentration of 6.4 ppm (TEQ), which makes them among the most dioxin-contaminated wastes ever discovered, on a par with wastes associated with the manufacture of Agent Orange.[94] In 2000, Norwegian scientists reported finding "extremely high" concentrations of dioxins and furans—26.6 ppm (60.7 ppb TEQ) —in the sludges from a VCM/EDC manufacturing plant. Considerable quantities of dioxins and furans had migrated from an on-site disposal facility for these sludges into groundwater, a nearby brook, and the Gulf of Finland in the Baltic Sea. Dioxin and furan levels in several fish species in the region of the plant were 2 to 9 times higher than levels in fish caught from a relatively uncontaminated local comparison area. Considerable quantities of PCBs were also found in sediments near the plant and were attributed to the production of EDC/VCM.[95]

The wastes from EDC synthesis have one of two major destinations. In some facilities, wastes are used in the manufacture of chlorinated solvents—wherein the contaminants end up in the wastes or products from those processes. In other facilities, the wastes are disposed of, usually by incineration. (A discussion of environmental releases from this practice follows). But not all by-products of EDC/VCM synthesis end up in the hazardous wastes—some escape directly into the environment. Dioxins have been detected in wastewater discharges and air emissions from a number of EDC/VCM plants,[96] and local and regional contamination of water, sediments, and shellfish has been linked to EDC/VCM manufacturers in Europe and the United States.[97] For example, severe dioxin contamination of sediments in Italy's Venice Lagoon has been linked to an EDC/VCM manufacturing facility.[98] In the Netherlands, levels of dioxins in sediment samples in the River Rhine jump dramatically immediately downstream from an EDC/VCM manufacturing plant.[99] The levels are so high, in fact, that the majority of dioxins in Rhine sediments downstream from the plant—all the way to the river's mouth, and in the entire North and Wadden Seas—appear to be attributable to the facility.[100]

These dioxin releases contribute not only to environmental contamination but also to human exposure. In Lake Charles, Louisiana, the U.S. Centers for Disease Control reported that residents in the Mossville area—located across the road from a large vinyl chloride manufacturing facility—have blood levels of dioxins and furans (TEQ) averaging nearly three times those of a comparison population (an increase that was statistically significant at the 95 percent confidence level). Eggs from chickens raised in the area were found to contain dioxins and furans at levels nearly double those in store-bought eggs; but the sample size was too small for statistical significance to be evaluated. The study did not evaluate specifically whether the increased dioxin levels were due to releases of dioxin from the EDC/VCM synthesis, from on-site incinerators for production wastes, or from some other process at facilities in the area.[101]

Other by-products are also present near chemical plants that make PVC feedstocks. In Lake Charles, Louisiana, the National Oceanic and Atmospheric Administration (NOAA) found high levels of persistent organochlorines in the water, sediment, and fish of bayous near EDC/VCM facilities owned by PPG and Vista Chemical. According to NOAA, the geographical pattern of contamination indicates that PPG is the primary cause of high levels of organochlorines in the water and sediment. In one portion of the estuary near PPG's facility, concentrations of HCB, HCBD, and HCE exceeded 1,000 ppm in

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[94] Costner et al. 1995.
[95] Isosaari et al. 2000.
[96] DTI 1995; Environment Agency 1997; SFT 1993.
[97] Contamination in the UK is described by Environment Agency 1997; in Germany by Lower Saxony Ministry of Environmental Affairs 1994; and in the United States by Curry et al. 1996.
[98] Ramacci et al. 1998.
[99] Evers et al. 1988.
[100] Evers et al. 1993; Evers et al. 1996.
[101] U.S. Centers for Disease Control 1999.

sediment; in some samples, these three by-products represented from 0.1 percent to an extraordinary 4.8 percent of the sediment's total mass.[102]

POLYMERIZATION, COMPOUNDING, AND MOLDING

Polymerization of VCM to make pure PVC is a more diffusely structured industry than EDC/VCM synthesis, with smaller quantities of product made at a greater number of facilities. No estimates of the total quantity of VCM released into the workplace and the local environment in these stages are available. Traditionally, worker exposure in this sector has been assumed to be higher than in any other process.[103] As previously discussed, numerous studies of the health of workers in PVC polymerization facilities have been conducted, and they have established a causal connection to angiosarcoma of the liver and revealed statistically significant excesses of brain cancer and neurological effects among VCM-exposed workers. In the United States, worker exposure in this sector has declined in recent decades.

Release of phthalates into the environment and occupational exposure to these substances is another issue in the later manufacturing stages of the vinyl lifecycle. In 1997, chemical and plastics industries in the United States reported releasing 213,621 pounds of the plasticizer diethylhexyl phthalate (DEHP) directly into the air, plus 71,004 pounds into the land.[104] Occupational exposures can be significant: in one plastics molding facility, DEHP levels have been measured at 11,500 nanograms per cubic meter, thousands of times higher than the levels typically found in outdoor air.[105] According to the National Toxicology Program, "workers may be exposed to relatively high concentrations during the compounding of DEHP with PVC resins. The major route of exposure is inhalation."[106]

There are few direct studies of health impacts and phthalate exposure in the PVC manufacturing industry. Two studies by a research group in Sweden indicate an increased risk of testicular cancer among workers in PVC manufacturing industries. In the first study, a variety of occupational exposures were investigated for a possible link to testicular cancer. Work in plastics production was found to cause a 2.9-fold increase in the risk of testicular cancer.[107] The second study tested and clarified the relationship between plastics work and testicular cancer. In this report, using a case-control study of 163 men with testicular cancer and 326 without the condition, occupational work with PVC plastic was associated with a 5.6-fold increase in the risk of seminoma—the form of testicular cancer that occurs later in life and may thus plausibly be caused by occupational exposure. The increased risk was statistically significant and highest among those men with the greatest cumulative exposures. No significant increases in the testicular cancer rate were seen among men who worked with other types of plastics. Because exposure to endocrine-disrupting compounds can lead to testicular cancer, the authors hypothesized that exposure to phthalates used as plasticizers in PVC—some of which are known endocrine disrupters and testicular toxicants—may be the specific cause of the increased risks.[108] These results contrast with those of a Danish study that found no relationship between work in cable manufacture—a large consumer of PVC—and testicular cancer.[109]

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[102] Curry et al 1996.
[103] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[104] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[105] Rudell et al. forthcoming.
[106] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[107] Hardell et al. 1998.
[108] Hardell et al. 1997; Ohlson and Hardell 2000.
[109] Hansen 2000.

DISPOSAL OF EDC/VCM WASTES

The organochlorine-rich heavy ends produced by EDC/VCM manufacture are regulated as a hazardous waste in the United States. The majority of these are disposed of by incineration, usually in on-site furnaces at the production facility. In theory, a properly designed and operated incinerator converts organochlorines by oxidation into carbon dioxide, hydrogen chloride, and water. Real-world combustion systems, however, never take this reaction to completion for all the compounds fed into them. Most compounds are completely oxidized, but some fraction escapes unburned, and a larger portion is converted into new organic compounds, called products of incomplete combustion (PICs). According to EPA's technical review document on hazardous waste incineration, "The complete combustion of all hydrocarbons to produce only water and carbon dioxide is theoretical and could occur only under ideal conditions…Real world combustion systems…virtually always produce PICs, some of which have been determined to be highly toxic."[110]

By-products form in incinerators for the same reasons as in chemical manufacturing: multiple reaction pathways, local optima that lead to stable by-products, and deviations from optimal conditions. In incineration, the problems are particularly acute—wastes are complex mixtures of diverse materials that can never be uniformly blended. Further, combustion is by nature a stochastic process of bond breakage and formation; at high temperatures, most of the molecules will be completely oxidized, but some will follow alternative reaction pathways and emerge as PICs. Transient variations and upsets are a particular problem with incinerators. Good management can reduce but never eliminate the production of PICs, as EPA's analysis made clear:

> [Deviations from optimum] usually are a consequence of a rapid perturbation in the incinerator resulting from a rapid transient in feed rate or composition, failure to adequately atomize a liquid fuel, excursions in operating temperature, instances where the combustible mixture fraction is outside the range of good operating practice, or inadequate mixing between the combustibles and the oxidant…The amount and composition of PICs will depend in a complex and unpredictable way on the nature of the perturbation.[111]

The type of incinerator and how well it is operated will affect the magnitude of the PICs released, but the production of chlorinated PICs—including the most hazardous ones like the dioxins and furans—is a universal and inevitable outcome whenever chlorinated wastes are burned. As the British Department of the Environment noted, "Comprehensive tests have established that all waste incinerators, independent of type of incinerator or waste composition, are likely to produce all of the possible 75 PCDD and 135 PCDF isomers and congeners, as well as about 400 other organic compounds."[112]

By-products form from diverse and unpredictable reactions not only in the furnace but also in the cooler zones, where control over combustion conditions is nearly irrelevant.[113] Dioxins can even form in pollution control devices or smokestacks, where chlorine gas, hydrochloric acid, or organochlorine precursors come in contact with organic compounds in fly ash. This process, called de novo dioxin formation, is greatly accelerated if iron or copper catalysts are present, as they are in EDC/VCM wastes and municipal trash.[114]

This means that incinerators not only destroy organochlorines, as they are supposed to, but also manufacture them. EPA estimates that PICs formed in the incineration process number in the

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[110] EPA 1990.
[111] EPA 1989.
[112] UKDOE 1989.
[113] Dellinger et al. 1988; EPA 1994b.
[114] Gullett 1990.

thousands.[115] Of these, some have been characterized, and the rest remain unidentified. Laboratory tests show that burning methane—the simplest possible hydrocarbon—in the presence of a chlorine source produces more than 100 organochlorine PICs. These by-products, ranging from chlorinated methanes to dioxins, are produced by a set of reactions thought to be common to all incineration processes in which chlorine is present.[116] It is much more challenging to analyze PICs in the stack gas of real-world incinerators, but more than 50 organochlorines or groups of organochlorines have been identified in the emissions of hazardous waste incinerators—ranging from the structurally simple carcinogen carbon tetrachloride to highly persistent and bioaccumulative compounds like chlorinated hexanes, dioxins, ethers, furans, naphthalenes, PCBs, phenols, and thiophenes.[117]

As in other aspects of the vinyl lifecycle, the identified compounds are just the beginning. At hazardous waste incinerators, the most comprehensive research burns have identified about 60 percent of the total mass of unburned hydrocarbons in incinerator stack gases, and most field tests have had far less success in identifying the PICs emitted.[118] There is good reason to be concerned about these mystery compounds because at least some appear to be in the same toxicological family as dioxins. German researchers measuring the dioxin-like toxicity of trash incinerator fly ash using a biological test found that toxicity was up to five times greater than could be accounted for by the amount of dioxins, furans, and PCBs in the ash.[119] The remaining dioxin-like effect was presumably caused by scores of other compounds—such as chlorinated naphthalenes, diphenyl ethers, thiophenes, and many others—that can cause similar health effects but were not specifically measured.

The total quantity of PICs and unburned wastes emitted from incinerators is not known precisely, but it appears to be large. In the United States, hazardous waste incinerators must pass a trial burn that requires them to demonstrate a destruction and removal efficiency (DRE) of 99.99 percent of the organic compounds fed to them, which means that no more than 0.01 percent of several test chemicals fed into the furnace may be measured in stack emissions. But high DREs do not mean that the environment is protected, for several reasons.

- EDC heavy ends are burned in such immense quantities that even if all incinerators achieved 99.99 percent DRE, they would still emit more than 6,600 pounds per year of unburned hazardous wastes into the air in the United States alone.[120]
- Much greater amounts of organochlorines are released as PICs. "Destruction" means only that the chemical tested was transformed into some substance other than the original compound, and PICs are not counted against the 99.99 percent DRE figure. EPA's Science Advisory Board has estimated that the total quantity of PICs that hazardous waste incinerators emit to the air may be up to 1 percent of

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[115] EPA 1989.

[116] Eklund et al. 1988. Similarly, combustion under well-controlled laboratory conditions of trichloroethylene, another relatively simply organochlorine, produces a variety of persistent organochlorine PICs, including hexachloropentadiene, highly chlorinated benzenes and indenes, PCBs, and the dioxin-like chlorofulvalenes (Blankenship et al. 1994).

[117] Trenholm and Lee 1986; Trenholm and Thurnau 1987; Dellinger et al. 1988; Chang et al. 1988; EPA 1987a and 1987b; Wienecke et al. 1995.

[118] EPA 1990.

[119] Markus et al. (1997) used a calibrated bioassay to quantify the activity of the cytochrome p4501A1 enzyme, which is induced by dioxin and serves as a "sensitive and selective" marker of dioxin exposure. The total dioxin-like toxicity of the fly ash exceeded that predicted by the quantity of dioxins, furans, and PCBs in the sample by a factor of two to five.

[120] Assuming incineration of 30,000 tons of EDC heavy ends per year.

the organic matter fed to them.[121] This estimate suggests that incineration of heavy ends from vinyl manufacture would emit some 660,000 pounds of PICs each year.

- Still more unburned wastes and PICs are transferred to the land or water where the ash, sludge, and effluent from incinerators are disposed of. These quantities are not included in a DRE, which reflects not only destruction of waste chemicals but also their removal by pollution control devices. An incinerator with a filter that captures 95 percent of the dioxin in the stack gas deposits 20 times more dioxin in its ash than it emits into the air, without any effect on the calculated DRE.

- DREs are calculated from an incinerator's performance when burning test chemicals that are fed in high concentrations, but two EPA studies have found that substances in low concentrations burn much less efficiently. Chemicals that are present in wastes in the ppb or ppm range—such as the dioxins, PCBs, and many other by-products in EDC/VCM wastes—are subject to destruction efficiencies as low as 99 percent, implying that significant amounts of these hazardous substances will escape intact from incinerators.[122]

- DREs measured in trial burns are unlikely to reflect emission rates during routine operation because trial burns involve the combustion of simplified mixtures of pure chemicals under carefully controlled, closely scrutinized conditions. In daily use, incinerators generally perform less efficiently, due to the complexity of real-world wastes and the frequency of upsets, operator error, and equipment malfunction.[123] Further, the standard trial burn protocol allows the measurement of emissions to stop when the feed of waste chemicals to the incinerator stops, but emissions can continue for days, resulting in total emissions of unburned wastes that are orders of magnitude greater—and DREs far lower—than those measured during the trial burn.[124]

For these reasons, an incinerator burning EDC/VCM manufacturing wastes may be certified as achieving 99.99 percent DRE when, in fact, it is emitting huge quantities of unburned and partially burned wastes into the environment.

VINYL INSTITUTES'S SELF-CHARACTERIZATION OF DIOXIN RELEASES

The Vinyl Institute (VI) has argued that its role in dioxin formation is minimal, primarily based on its own study, called the "dioxin self-characterization."[125] In this report, the Vinyl Institute concludes that the U.S. PVC industry releases about 13 grams of dioxin (TEQ) per year to the environment. This estimate is also the basis for the Vinyl Institute's contention that vinyl production is responsible for only a small fraction of identified dioxin releases in the United States.[126]

There are three reasons to be skeptical of the industry's reassurances about its dioxin emissions:

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[121] EPA SAB 1985.
[122] Kramlich et al. 1989; Trenholm et al. 1984.
[123] See, for instance, the 1986 analysis by U.S. EPA engineers (Staley et al. 1986), which concluded, "There are several problems with the permitting process [based on trial burns]. First, the trial burn data only indicate how well the incinerator was operating during the time that the data were being taken, typically only a period of a few days. No information is obtained on how the incinerator might respond if fuel, or especially waste, conditions change. Waste streams vary widely in composition and one incinerator may burn many different toxic substances over its useful life, resulting in unavoidable and frequent changes in waste feed conditions. It is difficult to generalize the results of a trial burn to predict how the composition of the incinerator exhaust will change under these varying conditions."
[124] Licis and Mason 1989.
[125] Vinyl Institute 1998.
[126] Burns 2000.

- Even if the Vinyl Institute's estimate is accurate, 13 grams of dioxin per year is still highly significant, justifying action to reduce vinyl consumption. U.S. EPA's current standard for the acceptable daily dioxin intake of an average adult (weighing 70 kg) is 0.153 billionths of a gram per year.[127] Based on its own estimates, then, the vinyl industry's annual releases of dioxin into the environment equal the acceptable annual dose for about 85 billion people. (Not all of the dioxins released by the industry will result in direct human exposures, of course. The point of this calculation is to demonstrate that, because dioxin is so exquisitely toxic, a quantity of dioxin that appears small on a mass basis is in fact extremely significant from a toxicological perspective.)
- The Vinyl Institute's figures on its dioxin releases are likely to be gross underestimates because they omit the majority of the dioxin produced during the vinyl lifecycle. The industry's self characterization analyzed several potential pathways for dioxin release, finding low to moderate quantities of dioxins and furans in samples of EDC, PVC products, air emissions, and wastewater and sludge from its treatment. But numerous pathways that contain the largest amounts of dioxin—along with many PVC-related processes that are major dioxin sources—were completely ignored. No data, for example, were gathered on dioxin contamination of chemical streams that re-circulate in the manufacturing process, of light ends and other wastes used in other synthesis processes, and—most importantly, because these are known to be so severely contaminated—heavy ends, tars, and other hazardous wastes that are sent to disposal facilities. Nor did the program address what is apparently the largest PVC-related dioxin source—the burning of vinyl in incinerators, smelters, and accidental fires. Thus, the industry's estimates are grossly incomplete and do not effectively refute the argument that the lifecycle of PVC is a major dioxin source.
- The Vinyl Institute's estimates have not been independently verified. In this self-characterization, the PVC industry decided when and where to take samples, how to collect them, how to analyze dioxin content, which data to present, and how to interpret this data before submitting their results to EPA. While an independent panel reviewed the submission, the industry chose which data the panel saw. Information about the samples—including which facility they came from—was completely confidential, so neither reviewers nor the public had the opportunity to determine whether sampling times and locations accurately represented typical dioxin releases. Most importantly, no one was able to independently evaluate, confirm, or act on the information.

It would be naïve to take at face value the industry's own estimates of the magnitude of its releases of dioxin—a substance that is the subject of major public concern and regulatory activity—particularly when those estimates conflict with a large body of information gathered by independent sources, such as those cited above.

[127] EPA 1985. The "acceptable" dose (0.006 pg/kg of body-weight/day) is the daily exposure that poses a calculated lifetime cancer risk of one per million.

Table 2 Mercury releases from the world chlor-alkali industry, 1994

	Metric tons of mercury per year[1]	PVC attributable portion[2]
Total consumption	229.8	91.9
Air emissions	26.3	10.5
Discharges to water	2.8	1.1
Contaminants in products	5.5	2.2
Disposed on land	157.8	63.1
Unaccounted for	36.0	14.4

1. Assuming 39 million metric tons per year of chlorine production worldwide, of which 35.5 percent was produced by the mercury process.

2. Assuming that PVC accounts for 40 percent of chlorine consumption worldwide and that an equal fraction of the chlorine produced in mercury cells is used for PVC; the Vinyl Institute has argued that the attributable fraction for mercury is 20 percent in the United States.

Note: These data are based on mass balances prepared by the chlorine industry for facilities in Europe and may not accurately represent global averages.

Source: Ayres 1997.

Table 3 Releases of EDC and VCM in PVC production stages; Norwegian government estimates, 1993

	Grams released per ton of product			
Product	EDC to air	EDC to water	VCM to air	VCM to water
EDC synthesis (1 ton)	–	7	–	–
VCM synthesis (1 ton)	5000	1	1000	1
PVC polymerization (1 ton)	–	–	5100	–

– Indicates releases <1 g/ton.

Source: SFT 1993.

3. USE OF PVC PRODUCTS

PVC is not bioavailable, so the polymer itself is not toxic during use. But vinyl products are not pure PVC; they contain both accidental contaminants and chemical modifiers that are added to the plastic on purpose, and some of these may pose health hazards. Moreover, PVC products often encounter reactive conditions—accidental fires in particular—that can transform the plastic into hazardous by-products.

BY-PRODUCT FORMATION

Some portion of the diverse organochlorine by-products created in the synthesis of EDC/VCM end up in the PVC itself. In May 1994, the Swedish Environmental Protection Agency found that pure PVC plastic from two Swedish producers contained dioxins, furans, and PCBs at concentrations ranging from 0.86 to 8.69 ppt TEQ.[128] In 1995, the UK government found dioxins and furans in the same range in PVC food packaging items, including cling film and bottles for oils and beverages.[129] Subsequently, the U.S. Vinyl Institute and the European plastics industries conducted their own studies, both of which identified trace quantities of some dioxin congeners in some samples of PVC plastic.[130] The levels were very low, but any quantity of dioxin in consumer products is a matter of concern.

INDOOR AIR QUALITY: RELEASE OF TOXICANTS

Because chemical additives are present in PVC in large amounts, they are particularly problematic. PVC additives include a range of toxic compounds, but the most important of these are the phthalate plasticizers and metallic stabilizers. Phthalates can make up a large portion—up to 60 percent by weight—of the final vinyl product.[131] Flexible PVC—including flooring, roofing membranes, and wall coverings—accounts for more than half of all vinyl demand, while the remainder is rigid, unplasticized materials such as pipes and siding.[132] Stabilizers—including lead, cadmium, organotins, and other compounds—are used to extend the life of PVC products exposed to light, and they are typically present in lower but still significant concentrations. About 5.4 million tons of phthalates and 156 thousand tons of lead are used each year in the worldwide production of PVC.[133] Vinyl accounts for more than 90 percent of the total consumption of phthalates, so the health and environmental impacts of phtahatles are overwhelmingly attributable to PVC.[134]

The additives are not chemically bonded to the PVC polymer but are mixed into the plastic during its formulation. Over time, these additives leach out of vinyl products, entering the air, water, or other liquids with which the product comes in contact. When PVC containers and films are used to hold food products, plasticizers migrate out of the plastic and accumulate in foods, especially fatty ones like cheese and meats.[135] The common practice of storing blood and drug formulations in PVC bags causes phthalates

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[128] SEPA 1994.
[129] MAFF 1995.
[130] Wagenaar et al. 1996; Carroll et al. 1996.
[131] DTI 1995.
[132] These figures are for Western Europe (European Commission 2000); in the U.S., where unplasticized vinyl siding is more widely used, the relevant figure may be slightly lower.
[133] My calculations are extrapolated from the figures for Sweden, where the lead input into PVC equals 0.653 percent of total PVC production, and the phthalate input equals 22.6 percent (TNO Centre for Technology and Policy Studies 1996), assuming 24 million tons of PVC production worldwide.
[134] TNO Centre for Technology and Policy Studies 1996.
[135] DTI 1995.

to leach into the container's contents, which can result in substantial short-term phthalate exposures for the recipient.[136] Newborn infants receiving a single blood transfusion have been found to have extremely high levels of phthalates in their systems.[137] When exposure is repeated, blood levels of phthalates can be 100 to 1,000 times greater than "background" and can reach levels at which liver damage and birth defects can occur in animals.[138] Phthalates are also released in significant quantities into saliva when small children suck on vinyl toys and teethers.[139]

Release of phthalate plasticizers

Of particular relevance to the health and environmental impacts of building materials is the release of phthalates into indoor air from flexible PVC. The plastics industry has argued that most phthalates have low vapor pressures; therefore they are not expected to volatilize much.[140] But this prediction is not borne out by experience: empirical data make clear that phthalates are released in considerable amounts from vinyl products into the indoor atmosphere. For example, DEHP levels in indoor air average 20 to 103 nanograms per cubic meter, compared to 0.3 to 4.0 nanograms per cubic meter in outdoor air.[141] As one review concluded, "Phthalates are typically present in indoor air at much higher concentrations than outdoor air due to their high concentrations in consumer products and building materials."[142] According to figures cited by the National Toxicology Program, inhalation accounts for about 15 percent of the average adult's daily intake of DEHP.[143]

The relatively low vapor pressure of most phthalates may explain their tendency to be present on dust particles in higher concentrations than in the vapor phase. One U.S. study of indoor dust and air samples taken from homes and offices found substantial levels of all phthalates tested. Levels were highest of DEHP and butyl benzyl phthalate (BBP), which were present in dust at the remarkably high mean levels of 315 and 117 ppm, respectively.[144] Another recent study of indoor air in Norwegian residences had similar findings, reporting an average of 960 ppm (including 640 ppm of DEHP and 110 ppm of BBP) on sedimented dust particles and 1,180 ppm (more than 0.1 percent) on suspended dust particles.[145] This study also found that a large portion of the phthalate-contaminated dust particles were small enough to be taken into the airway and lungs. As discussed later, phthalates impair reproduction and development, and some are suspected carcinogens.

Asthma and other conditions

The high levels of phthalates in indoor air suggest the possibility that these compounds may contribute to the risk of asthma—the cases of which have been steadily increasing in recent decades—particularly among children. In 1997, an analysis of phthalate levels in indoor air pointed out that MEHP—the primary metabolite of DEHP—induces bronchial hyper-reactivity in rats, presumably by its ability to bind to and activate the receptor for prostaglandin D2, a locally-acting hormone that triggers inflammation. This report concluded, "We propose that the increase in asthma is due to contributory factors of environmental chemicals in general, and specifically DEHP through its primary hydrolysis product

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[136] Pearson and Trissel 1993; Goldspiel 1994.
[137] Plonait et al. 1993.
[138] Dine et al. 2000; National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[139] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a and 2000c.
[140] American Chemistry Council 2000.
[141] Rudell 2000.
[142] Rudell 2000.
[143] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[144] Rudell et al. forthcoming.
[145] Oie et al. 1997.

MEHP, which affects the bronchial contracting receptors and thereby generates a hyperreactive condition in the lungs. This will increase the risk of a pathological development in addition to aggravation of the effects of other environmental agents."[146]

Three epidemiological studies have tested this hypothesis and found evidence that exposure to PVC in building interiors increases the risk of asthma and related conditions. The first study of 251 Norwegian children with bronchial obstruction, with an equal number of healthy children for comparison, found that the presence of PVC flooring in the home was associated with a statistically significant 1.9-fold increase in the risk of bronchial obstruction. Further analysis revealed a dose-response relationship between the amount of PVC and other plasticizer-containing materials in the home and the risk of this condition—a finding that increases confidence that the association between exposure and risk is not a spurious one.[147]

A larger follow-up study in Finland found that children in homes with PVC flooring or wall covering were significantly more likely to suffer from asthma, persistent wheezing, pneumonia, prolonged cough, and phlegm in the airway. The researchers concluded, "Emissions from plastic materials indoors may have adverse effects on the lower respiratory tracts of small children…Our findings provide additional evidence that indoor plastic materials may emit chemicals that have adverse effects on the lower respiratory tracts of small children…and warrant further attention to the types of plastic materials used in interior decoration."[148]

A third study focused on the presence of certain breakdown products of DEHP in indoor air. This report by Swedish researchers examined the prevalence of symptoms of eye and nasal irritation, as well as biochemical indicators of inflammation and secretion in these tissues, in relation to the presence of 2-ethyl-1-hexanol (EH) in indoor air. EH is the primary breakdown product of DEHP in damp conditions, which sometimes occur when floors or walls that are covered with an impermeable layer of vinyl become wet. The study examined the staff of four nursing homes—three with PVC flooring, and one without. Workers in the two buildings with damp PVC surfaces were exposed to higher levels of EH and had significantly increased symptoms of nasal and ocular irritation, as well as of biochemical indicators. Other indoor air factors could not explain the finding, as levels of formaldehyde, molds, bacteria, ozone, and NO_2 were low in all four buildings. The authors concluded, "Emissions related to the degradation of DEHP due to dampness in the floors…may affect the mucous membranes in the eyes and nose, decrease tear film stability and increase the occurrence of ocular and nasal symptoms. The low occurrence of both symptoms and signs in the building with special materials and design illustrates that it is possible to construct a new building with a minimum of adverse effects on nasal and ocular membranes."[149]

This evidence does not prove that PVC is a major cause of asthma, but it justifies concern about the role of indoor exposure to phthalate plasticizers in relation to this widespread condition and action to reduce exposures.

Toxic mold growth

Vinyl's tendency to trap dampness can create another indoor air problem—the growth of toxic molds. Some molds produce toxic and/or allergenic products, particularly among sensitive individuals. These molds do not normally grow indoors but can grow on persistently damp surfaces that contain nutrients (including gypsum and sheetrock), if they are suitably warm and protected from drying out. Repair of the mildewed material has cost millions of dollars, and liability claims are on the rise for property damage

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[146] Oie et al. 1997.
[147] Jaakola et al. 1999.
[148] Jaakola et al. 2000.
[149] Wieslander et al. 1999.

and personal injury caused by mold growing inside buildings, including headaches, skin rashes, memory loss, respiratory problems, lung disease, and brain damage.[150] Vinyl wallcoverings, because they are impermeable to water vapor, are said to be the major cause of mold and mildew in interiors, according to several building industry sources.[151] The vinyl industry confirms that vinyl wall coverings have created this situation in many buildings; PVC acts as "a vapor barrier that traps moisture inside the wall cavity, where it condenses against the relatively cool inside surface of the wall. Prolonged exposure to these conditions will result in deterioration of the gypsum board."[152] The industry suggests that use of permeable membranes on the outside wall part of the cavity and prevention of moisture infiltration can help reduce the risk of mildew growth.[153] Because dampness and condensation can occur inside vinyl-sealed walls from temperature and humidity differentials produced by heating and air conditioning systems, however, at least one authoritative building industry source recommends avoiding vinyl wallcoverings altogether to prevent mold and mildew growth.[154]

Releases of lead and other stabilizers

Metal stabilizers are also released from PVC products. Significant releases of lead have been documented from PVC window blinds,[155] leading to a warning by the U.S. Consumer Product Safety Commission. Lead is also known to leach into water carried in PVC pipes that contain lead stabilizers.[156]

But lead continues to be used in building-related materials, as are other hazardous additives. Lead stabilizers are commonly used in pipes, vinyl cables, and window profiles, although their use is greater in Europe than in the United States.[157] Lead accounts for nearly 70 percent of all vinyl stabilizers in Europe, with consumption of more than 51,000 tons of lead in PVC annually, based on 2000 estimates by the European Union.[158] Lead is an infinitely persistent substance and is exquisitely toxic to the developing brain—even in tiny amounts. In November 2000, the Danish government took action to ban the use of virtually all lead compounds, including those in PVC cables, gutters, pipes, roofing, and windows, by no later than 2003.[159]

PVC is also associated with other toxic metals. According to the European Commission, 50 tons (110,000 pounds) of cadmium—also a highly neurotoxic and infinitely persistent metal—are used in vinyl each year in Europe, although quantities are declining. Consumption of organotin compounds in vinyl is estimated at 15,000 tons, mostly in rigid films, roofing materials, and clear rigid construction sheeting.[160] Organotins used in vinyl can suppress the immune systems, cause birth defects, damage the liver, bile duct, and pancreas, and may pose hazards to the aquatic organisms when released into the environment.[161] Further, the mono- and di-butyl tin compounds used in PVC are contaminated with tributyl tin (TBT), a potent endocrine-disrupting compound that has caused major damage to marine wildlife populations.[162]

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[150] Hsieh 2000.
[151] Lstiburek and Carmody 1994; Downs 2001
[152] Vinyl Institute 2000.
[153] Vinyl Institute 2000.
[154] Lstiburek and Carmody 1994.
[155] *Chicago Tribune* 1996.
[156] DTI 1995
[157] European Commission 2000.
[158] European Commission 2000.
[159] ENDS 2000.
[160] European Commission 2000.
[161] European Commission 2000; Ema et al 1996; Merkord et al 2000; De Santiago and Aguilar-Santelises 1989.
[162] Kemi 2000.

ACCIDENTAL COMBUSTION

The possibility of fire is another major hazard associated with the use of PVC products. Vinyl manufactures often stress the materials' fire resistant properties—due to the high fraction of chlorine in PVC—as an advantage for hospitals, schools, and other public buildings. In fact, chlorine's resistance to combustion represents a hazard, not a benefit.

PVC is now ubiquitous in modern buildings and vehicles. When vinyl burns, the primary combustion products are carbon dioxide, hydrochloric acid, and water. In several major fires, hydrochloric acid has caused severe burns toskin, eyes, and lungs and is an important cause of toxicity to firefighters and persons exposed to fumes and smoke. It can also cause severe damage to computers and other equipment.[163] When large masses of PVC are present—as in vinyl siding or roofing membranes—the hazards may extend to building occupants and the surrounding community.

The hazards of PVC in fires have prompted action or positions by a number of expert organizations. The U.S. military has adopted specifications to avoid PVC-jacketed cables in aircraft, space vehicles, and enclosures in which offgassing may occur in the event of fire.[164] In the United Kingdom, the Fire Brigades Union (FBU) has stated, "The FBU is now particularly concerned about the safety of PVC based building materials that are used in the construction and fitting out of buildings when involved in fire."[165] The International Association of Firefighters has stated,

> Because of its majority chlorine content, when PVC burns in fires two hazardous substances are formed which present acute and chronic hazards to fire fighters, building occupants, and the surrounding community. These are hydrogen chloride gas and dioxin. Hydrogen chloride is a corrosive, highly toxic gas that can cause skin burns and when comes into contact with the mucous lining of the respiratory tract creates hydrochloric acid, which can cause severe respiratory damage. Exposure to a single PVC fire can cause permanent respiratory disease.
>
> Dioxin is an unintentional by-product of PVC combustion, and would most likely be left behind in ash and debris from a PVC fire. While only small amounts of dioxin may be formed as the result of burning PVC, it is one of the most toxic substances known to science. Dioxin is a known human carcinogen and has been linked to reproductive disorders, immune suppression, and endometriosis, and other diseases in laboratory animals.
>
> Due to its intrinsic hazards, we support efforts to identify and use alternative building materials that do not pose as much risk as PVC to firefighters, building occupants or communities.[166]

Accidental fires provide very poor combustion conditions, so substantial amounts of dioxin and other organochlorines form as products of incomplete combustion in a vinyl fire.[167] Indeed, the combustion conditions in an accidental fire, where gases do not mix thoroughly and materials cool rapidly as they escape from the flame, are considered optimal for the rapid production of dioxins.[168] As a result, all accidental fires in buildings containing PVC are likely to generate dioxins and other persistent, bioaccumulative organochlorines. For example, in Germany after a fire in a kindergarten that contained substantial quantities of PVC, scientists measured dioxin levels in indoor soot at concentrations of 45,000 ppt (TEQ) —almost 300 times greater than the German government's health standard. This situation required the building's interior to be completely stripped of PVC—all floors, ceilings, wall coverings,

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[163] Markowitz et al. 1989; Markowitz 1989; Wallace 1990.
[164] U.S. Navy 1986.
[165] Cameron 1996.
[166] Duffy 1998.
[167] Wirts et al. 1998; Christman 1989; Theisen et al. 1989.
[168] TNO Centre for Technology and Policy Studies 1996.

furnishings, and so on—sandblasted, and remediated by hazardous waste experts before children were allowed to enter again.[169] Dioxins have also been identified in the residues from burning automobiles, railway coaches, and subway cars.[170]

Even a small amount of dioxin from each of the 621,000 structural fires and 421,000 vehicle fires in the United States each year could substantially contribute to dioxin contamination of the environment.[171] The German EPA and the German Environment Ministers have called for the use of substitutes for PVC in all areas susceptible to fire, but PVC use in construction continues to grow on a global basis.[172] As a result, a stockpile of PVC, waiting to burn, is accumulating in immense quantities. Worldwide, more than 400 million tons of PVC are "in stock"— that is, in use in various applications, mostly construction-related, and susceptible to fire at some point.[173] The Vinyl Institute has argued that PVC fires are probably a relatively small contributor to the total dioxin burden, based on a study that quantified dioxin levels in soot residues within a limited radius of a fire at a plastics facility.[174] But more than 90 percent of the dioxins produced in a structural fire are in the gaseous phase and escape into the atmosphere,[175] and an additional amount is transported beyond the local area, so this study is likely to have underestimated total dioxin emissions by at least a factor of ten. EPA has concluded that the data are currently inadequate to make a firm quantitative estimate of the contribution of accidental structural fires to national dioxin emissions.[176]

While many small fires taken together may constitute an important source of organochlorines, a single fire at a large commercial building, disposal site, PVC factory, or warehouse can generate large quantities of pollutants. A home contains at most a few hundred kilograms of PVC,[177] but a large building may contain much more. For example, a vinyl-lined roof on an average-sized school contains more than 10 tons of PVC,[178] and a plastics warehouse or landfill may have hundreds of tons on-site. After a fire at a plastics warehouse in Binghamton, New York, dioxin levels in soil on the site were found to be more than 100 times greater than other samples from the same community.[179] Elevated dioxin levels have also been reported in a university building after an interior fire in a lecture hall that contained PVC components.[180] According to the European Commission, fires are estimated to account for 6.6 percent of all dioxin emissions from identified sources (table 3).

PVC fires not only create dioxins and other organochlorines, they also release additives held in the plastic. The world stock of PVC in use contains a staggering 3.2 million tons of lead and 83 million

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169 Fiedler et al. 1993.
170 Versar, Inc. 1996.
171 Versar, Inc. 1996.
172 UBA 1992; German Environment Ministers 1992.
173 I have extrapolated from figures for Sweden (TNO Centre for Technology and Policy Studies 1996), which indicate that the stock of PVC in use (2 million tons) equals 22.47 years of current PVC production. I have assumed a similar stock-to-production ratio worldwide, and annual PVC production of 19.1 million tons per year (DTI 1995). Use of more recent figures for global PVC production would increase this estimate substantially (Kielhorn et al. 2000).
174 Carroll 1995.
175 Versar 1996; EPA 1998.
176 EPA 1998.
177 Carroll 1995.
178 Assuming a roof size of 80,000 square feet and a mass of 0.31 pounds of vinyl roofing membrane per square foot (Cummings 2001).
179 Schecter and Kessler 1996.
180 Deutsch and Goldfarb 1988.

tons of phthalates.[181] Since lead cannot be destroyed by combustion, accidental fires represent an important potential source of lead exposure—a hazard which looms larger as more and more PVC accumulates worldwide in building applications.

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[181] I have extrapolated from figures for Sweden (TNO Centre for Technology and Policy Studies 1996), which indicate that the stock of PVC in use (2 million tons) equals 22.47 years of current PVC production, which contains 15,000 tons of lead 288 thousand tons of phthalates. I have assumed a similar stock-to-production ratio worldwide, and annual PVC production of 19.1 million tons per year (DTI 1995). Use of more recent figures for global PVC production rates (Kielhorn et al. 2000) would increase this estimate by about 50 percent.

4. DISPOSAL OF PVC PRODUCTS

The final stage of PVC's lifecycle creates the most severe environmental hazards. About 30 to 50 percent of the vinyl produced annually—some 8 to 12 million tons per year worldwide—ends up in the trash stream.[182] EPA has estimated that at least 15 million tons of PVC are disposed of annually in the United.[183] Although some building materials have a relatively long lifetime, significant quantities of vinyl are disposed of as cutaways in preconsumer waste and, ultimately, in demolition or renovation wastes when a product's useful lifetime ends. Construction products are often thought of as a long-life sector of PVC use, but vinyl products in commercial interiors—often renovated well before their components are physically spent—have relatively short lifetimes.

RECYCLING

One thing is true everywhere: very little postconsumer PVC is recycled. A substantial portion of preconsumer PVC—scraps and cuttings from manufacturing stages—is recycled, but the quantities of preconsumer waste represent a small amount of the PVC waste stream. Recycling postconsumer PVC is extremely difficult because vinyl products are mixtures of PVC and additives, and each specific formulation is uniquely suited to its application. In virtually all post-consumer vinyl recycling, many formulations are mixed together, destroying the special properties of each. As a result, recycled post-consumer PVC is always of lower quality than the original material, so it can be used only in products without strict material requirements, such as fence posts and speed bumps.[184]

Since recycled PVC is almost never used to make a new version of the original product, down-cycling is a better term for the process than recycling[185] An example of true recycling is the reprocessing of paper: the old fibers are used to make new paper products, and a new tree does not need to be cut down. In contrast, a new vinyl wall covering or floor tile must be made of new plastic. Down-cycling does not reduce the amount of PVC produced each year or the total quantity of PVC building up on the planet. The illusion of recycling actually increases the global PVC burden by finding new uses for old PVC while creating a positive image for a product that can be neither safely disposed of nor truly recycled. As the European Commission put it, while true recycling has obvious environmental benefits, "the environmental advantages of the down-cycling of mixed plastics for the production of products which substitute concrete, wood, or other non-plastic applications are less certain."[186]

In the European Union countries, less than 3 percent of postconsumer PVC waste is recycled—the majority of which is actually down-cycling of cable and packaging wastes. According to a 2000 report by the European Commission, "high-quality mechanical recycling for post-consumer [vinyl] wastes is still in a preliminary stage and exists only for a few product groups and with low quantities."[187] Sweden, a nation with an ambitious and effecting recycling program, had a total PVC recycling rate of just 2 percent in 1999, nearly all of it preconsumer waste.[188] The European Commission projects that only 9 percent of all PVC waste is likely to be recycled by 2020, with a maximum potential of no more than 18 percent.[189]

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182 TNO Centre for Technology and Policy Studies 1996.
183 Franklin Associates 1997.
184 European Commission 2000.
185 DTI 1995.
186 European Commission 2000.
187 European Commission 2000.
188 KemI 2000.
189 European Commission 2000.

Such low recycling rates, even with time to develop an ambitious program, indicate that PVC is not and cannot be a green building material.

The American Association of Postconsumer Plastics Recyclers announced in 1998 that its attempts to recycle PVC had failed and that it would henceforth view vinyl products as unrecyclable contaminants in the municipal waste stream.[190]

There are also concerns about the potential environmental hazards of PVC recycling. Mechanical recycling of PVC can release additives, including phthalates and stabilizers, which may then be dispersed into the recycled products, into the environment, or, if they are captured, disposed of on land or in incinerators. The European Commission has recognized significant concerns about the presence of lead and cadmium stabilizers in PVC products that are recycled and their subsequent dispersal into a greater range of consumer products.[191]

LAND DISPOSAL

A significant portion of discarded PVC ends up in landfills, and almost all the remainder is burned—the exact proportions vary from one country to another. In landfills, there are three concerns about PVC disposal. First, the persistence of PVC, which typically lasts for centuries in a landfill, presents a significant burden in terms of the demand for landfill space. Second, the release of additives in the plastic can contaminate groundwater. Because phthalates and metals are not chemically bonded to the polymer, they can leach out of disposed products into landfill leachate, eventually contaminating groundwater.[192]

Third, fires can occur during or after the disposal process, releasing hazardous substances into the air, including dioxins and metals. In Hamilton, Ontario, for example, after some 200 tons of PVC burned at a plastics recycling facility, samples of ash, soot, and tree leaves from the fire area were found to contain elevated quantities of dioxins.[193] Of particular concern are landfill fires, which occur with some regularity at landfills and waste storage sites where large quantities of PVC are present. Data on dioxin releases from landfill fires are limited, but EPA estimates that landfill fires may emit on the order of 1,000 grams of dioxins and furans (TEQ) into the air each year in the United States, second only to trash incinerators among U.S. dioxin sources to the air.[194]

INCINERATION

Role of PVC in incineration

In every inventory of dioxin sources in the world, trash incinerators and other combustion sources account for the majority of identified dioxin releases into the environment (table 4), and PVC is the predominant source of dioxin-generating chlorine in these facilities. In municipal waste incinerators, PVC contributes at least 80 percent of the organically-bound chlorine and 50 to 67 percent of the total chlorine (organochlorines plus inorganic chloride) in the waste stream—although it makes up only about 0.5

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[190] APR 1998.
[191] European Commission 2000.
[192] European Commission 2000.
[193] Hamilton-Wentworth 1997; Socha et al. 1997. Socha et al. notes that dioxin levels in tree leaves downwind from the fire were 7 to 100 times above normal. Apparently, pollutants on the leaves were washed from the leaves into the general environment by rain, because levels on leaves declined significantly after the first post-fire rainstorm.
[194] EPA 1998.

percent of the trash stream by weight.[195] In the United States, an estimated 200,000 to 300,000 tons of PVC is incinerated in trash burners every year.[196] Large quantities of PVC also go to medical waste incinerators, where PVC accounts for 5 to 18 percent of the waste stream—more than 90 percent of the organic chlorine, and more than 80 percent of the total chlorine content of medical waste.[197] As table 3 shows, PVC is a major source of chlorine—and therefore of dioxin formation—in many of the major world's dioxin sources identified to date. In fact, sources in which PVC is the dominant chlorine donor account for 77 percent of all inventoried dioxin emissions in the U.S. and 50 percent in Europe.

Without a doubt, burning vinyl is a source of dioxin. Numerous laboratory combustion tests involving pure PVC (or pure PVC in the presence of metal catalysts) produce considerable amounts of dioxin.[198] No one has attempted to identify the full range of by-products that form when PVC burns, but 45 organochlorines—including persistent and toxic chlorinated benzenes, naphthalenes, PCBs, PCDFs, phenols, and styrenes—have been found in the combustion products when the closely related plastic polyvinylidene chloride (PVDC; commonly known as Saran Wrap) is incinerated.[199]

As in many other processes, the identified compounds are just the beginning. In municipal incinerators, the most thorough analysis to date identified several hundred PICs, including 38 organochlorines—chlorinated benzenes, ethylenes, methanes, PCBs, and others—but 58 percent of the total mass of PICs remained unidentified.[200] As noted above, a considerable portion of these mystery compounds are likely to be hazardous, and at least some are known to cause dioxin-like toxicity.

Incinerators also release additives contained in PVC products into the environment. An estimated 45,000 tons of lead stabilizers in PVC enter the world's municipal trash each year, based on Swdeish figures..[201] Because lead cannot be destroyed by incineration, all lead that enters an incinerator ultimately enters the environment via stack emissions, ash, scrubber effluent, or wastewater sludges. Incinerators are now the largest source of lead emissions into the environment; PVC is responsible for about 20 percent of the lead in the waste stream, according to Swedish figures.[202] In the European Union, vinyl contributes from 1 to 28 percent of the lead and 10 percent of the cadmium entering municipal waste incinerators.[203]

Not all vinyl burning takes place in high-tech incinerators. In developing countries and rural areas of industrial nations, open burning of waste is a common method to rid trash and debris. A recent study by U.S. EPA and the New York Department of Environmental Conservation indicates that backyard burning of trash in barrels can result in massive emissions of toxic chemicals, including chlorinated benzenes, methanes, phenols, as well as dioxins and furans. Emissions of dioxins and furans per pound of waste burned were 12,000 to 75,000 times higher than emissions from an optimally operated modern

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[195] Danish EPA 1993; Ecocycle Commission of the Government of Sweden 1994; DTI 1995; TNO Institute of Environmental and Energy Technology 1994.

[196] This assumes U.S. municipal waste incinerator capacity of 48 million tons per year (Versar 1996), 80 percent capacity utilization, and PVC content of 0.5 to 0.8 percent.

[197] According to two studies, 9.4 percent (Marrack 1988) and 15 percent (Hasselriis and Constantine 1993) of infectious red-bag waste in the U.S. is PVC, and as much as 18 percent of non-infectious hospital wastes are PVC (Hasselriis and Constantine 1993). In Denmark, PVC accounts for about 5 percent of all medical waste (DTI 1995). See also Green 1993.

[198] Christmann et al. 1989; Theisen et al. 1989; Theisen 1991.

[199] Yasuhara and Morita 1988. See also Blankenship et al. 1994.

[200] Jay and Stieglitz 1995.

[201] I have extrapolated from the relevant figures for Sweden, where 249 tons of PVC enter the waste stream each year (TNO Centre for Technology and Policy Studies 1996), assuming 19.1 million tons of PVC production worldwide, each year (DTI 1995).

[202] TNO Centre for Technology and Policy Studies 1996.

[203] European Commission 2000.

trash incinerator.[204] Further, when more PVC was burned, average releases of dioxin and all other chlorinated PICs rose substantially; the experiment did not include enough replications for the statistical significance of the increase to be evaluated. Although it is unlikely that construction or demolition waste from commercial buildings will be disposed of by uncontrolled burning, materials used in residential construction in rural areas and developing countries may be. The rapidly expanding use of vinyl in developing nations, where expensive means of waste management are not available, has the potential to cause a major increase in worldwide emissions of dioxins.

Some spent metal products that contain vinyl—including materials used in buildings such as cables and electronics equipment—are recycled or reprocessed in smelters, and these facilities are also major dioxin sources. Secondary copper smelters, for example, recover copper from PVC-coated wire and cable and PVC-containing telephone cases. High dioxin emissions have been measured at these facilities, which are considered major dioxin sources in most inventories.[205] Most importantly, removing some of the vinyl sheathing before cables are fed to the smelters reduces dioxin emissions considerably.[206] Secondary steel smelters have also been found to emit large quantities of dioxin, in part because they recover metal from scrap automobiles that contain PVC.[207] Secondary lead smelters release dioxin and other organochlorines, too, due to the feed of lead automobile batteries with internal PVC parts. In the United States, however, PVC has been recently phased out of this application, so EPA no longer considers lead smelters an important dioxin source.[208]

Dioxin Formation and PVC—Evidence from Combustion Experiments

Following an aggressive effort by the chemical and plastics industry, an apparent controversy has developed over whether burning PVC in incinerators results in increased dioxin emissions. The data, however, strongly support the view that dioxin forms when PVC and other organochlorines burn, and further that burning more PVC (or other organochlorines) results in the formation of more dioxin. This is not to say that the organochlorine content of the waste is the only factor involved in dioxin formation; facility design, operating conditions, and the presence of catalysts also play major roles. Chlorine is a requirement for dioxin synthesis, and preventing the introduction of organochlorines into incinerators is the best means to prevent dioxin formation. Conversely, because burning PVC is known to produce dioxin, burning more PVC will produce more dioxin, and burning less PVC will reduce dioxin generation.

Dioxin cannot be formed without a chlorine source, so emissions from incinerators must be the result of burning organochlorines, burning salt, or some combination of the two. To suggest that organochlorines are not important dioxin precursors requires burning organochlorines to produce little or no dioxin and the combustion of inorganic chloride salts to be the predominant source of dioxin. Several

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[204] Lemieux 1997. PCDD/F emissions (total) from an avid recycler with high PVC content in their waste averaged 269.6 micrograms per kilogram of waste burned; from a non-recycler with much lower quantities of PVC, and PCDD/Fs averaged 44.30 ug/kg of waste. There were only two runs for each type of trash, so conclusions about the role of PVC in dioxin emissions are tentative. EPA contrasted these high levels of dioxin emissions to those from a municipal waste combustor, which EPA estimated at 0.0035 ug/kg of waste. This figure may be lower than many incinerators in the real world, but the point that uncontrolled burning of waste produces relatively high quantities of dioxin is almost certainly correct. My estimate of the number of households required to produce the same amount of PCDD/Fs assumes, as EPA's report does, an incinerator burning 182,000 kilograms of waste per day, as compared to an average of 4.9 kilograms per day in non-recycling households.

[205] Christmann 1989; EPA 1994a; Versar, Inc. 1996.

[206] Christmann et al. 1989.

[207] Lahl 1994; Schaum et al. 1993; EPA 1994b; Aittola et al. 1993.

[208] Versar, Inc. 1996.

lines of evidence indicate that organochlorines—particularly PVC—are the most important and most preventable cause of dioxin emissions from combustors.

The first line of evidence comes from numerous well-conducted studies in the laboratory. Results from the laboratory are particularly convincing because, unlike trial burns at full-scale incinerators, they allow combustion conditions, emissions, and input materials to be carefully controlled and accurately monitored. Studies of this type indicate that burning PVC is clearly an important dioxin source.

- The German EPA has found that burning PVC or other organochlorines produces dioxin—with concentrations in ash residues ranging from 3.2 to 662 ppt (TEQ). But combustion of several types of organochlorine-free but chloride-containing cotton, paper, wood, or wool does not produce dioxin above the detection limit of 0.1 ppt[209] (table 5).
- Two separate studies by Danish researchers have found that burning pure PVC produces dioxin. Under some conditions, the quantities formed are quite large.[210]
- A 2000 report by Japanese researchers found that adding 4 percent PVC to a mixture of chlorine-free materials in a lab-scale incinerator had an "intense effect in dioxin emissions"—a more than 10-fold increase. Adding an equal quantity of salt caused at most a two-fold increase.[211]
- When newspaper or chlorine-free plastics are burned in a laboratory-scale incinerator, dioxin generation is extremely low. When PVC is added to the mix, dioxin levels in fly ash increase by a factor of 200 to 1,200—compared to 13- to 45-fold increase when salt is added.[212]
- When PVC is added to a mixture of chloride-containing coal and bark, dioxin concentrations in the residues increase by a factor of 10 to 100; the more PVC added, the higher the dioxin concentration.[213]
- Adding PVC during combustion of natural chloride-containing wood products increases dioxin levels in the ash by 15 to 2,400 times. When large quantities of chemical hardeners containing inorganic chloride are added, dioxin levels rise somewhat, but are still 3 to 350 times lower than when PVC is included in the mix.[214] A Swiss study confirmed these results, finding that dioxin levels in fly ash from the burning of waste wood that has been glued, painted, or otherwise processed are up to 2,000 times higher than in ash from the burning of natural wood.[215]
- Combustion of a mixture of coal and salt produces trace quantities of dioxins and furans in the off-gas, but when elemental chlorine is added to the mix, total dioxin formation increases 130-fold.[216]
- Burning chloride-containing vegetable matter does not produce detectable PCDD/Fs, but including PVC or chlorine gas along with the plant material does.[217]

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[209] Theisen 1991.
[210] Christman 1989; Vikelsoe and Johansen 2000
[211] Ishibashi et al. 2000.
[212] Takasuga et al. 2000. When fly ash from a municipal incinerator was added to the mix, baseline concentrations of dioxin were higher, and, as discussed below, addition of PVC or salt yielded similar increases in dioxin levels.
[213] Kopponen et al. 1992.
[214] Kolenda et al. 1994; Wilken 1994.
[215] Wunderli et al. 2000.
[216] Mahle and Whiting 1980.
[217] Liberti et al. 1983.

- The same pattern exists for other organochlorines. Finnish researchers have found that burning perchloroethylene in a laboratory combustion reactor produces more dioxins, chlorobenzenes, and chlorophenols than burning sodium chloride.[218] An American study found that formation of dioxin precursors rises as the proportion of organochlorines in the waste increases,[219] while three others have found that adding salt to a combustion reaction has no detectable effect on dioxin formation.[220]

In full-scale or pilot-scale incinerators (units smaller than commercial burners but similar in design), the evidence also supports a relationship between burning organochlorines and creating dioxin, but there are also some contradictory studies, possibly due to the difficulty of analyzing complex input and output streams and adjusting for fluctuating operating conditions:

- The Danish EPA has found that doubling the PVC content of an incinerator's waste input increases dioxin emissions by 32 percent, while doubling the chloride content increases dioxin emissions by a much smaller margin.[221]
- A team of Japanese researchers has reported on two separate sets of experiments that showed burning a mixture of PVC and polyethylene—in which PVC is the only chlorine source—produces substantial quantities of dioxin.[222]
- Two groups of researchers from Finland have found that dioxin levels in stack gas or fly ash are very low when a mixture of coal and chlorine-free plastics is burned, but rise substantially when PVC is added to the mix.[223]
- A 1996 study for the Dutch Environment Ministry reported that when both PVC and chloride-containing compostable matter are removed from municipal waste, emissions of chlorophenols—indicator compounds for dioxin formation—were extremely low. When 20 percent of the original amount of compostables was added back into the mix, emissions did not increase, but when 30 percent of the original amount of PVC was added along with the compostables, chlorophenol emissions approximately doubled.[224]
- A series of studies at a pilot-scale incinerator at the University of Florida has documented a clear relationship between the feed of PVC and the emission of chlorophenols. The authors summed up their findings: "These experimental, phenomenological and theoretical studies of toxic emissions from incineration all support the physically intuitive hypothesis that reduction of chlorinated plastics in the input waste stream results in reduction of aromatic chlorinated organic emissions.... We are convinced that, when all other factors are held constant, there is a direct correlation

[218] Halonen et al. 1995

[219] Altwicker et al. 1993. In this study, increasing the feed of organically-bound chlorine results in a substantially higher ratio of chlorophenols to chlorobenzenes in the combustion products; chlorophenols are considered precursors for dioxin formation.

[220] Bruce et al. (1991) found that addition of potassium chloride, sodium chloride, or calcium chloride to a combustion reaction had no effect on the quantities of dioxins and furans formed and deposited in the fly ash. Addink et al. (1998) added sodium chloride to fly ash and found that it did not participate in the de novo formation of dioxins and furans. Lenoir et al. (1991) burned sodium chloride with polyethylene in a fluidized bed combustor and found no effect on the amount of dioxins and furans emitted.

[221] Danish Environmental Protection Agency 1993.

[222] Tamade et al. 2000; Yoneda et al. 2000.

[223] Mattila et al. 1992; Ruuskanen et al. 1994; Frankenhauser et al. 1993.

[224] This study by Kanters et al. (1996) focused on emissions of chlorophenols as a surrogate for dioxin, due to the difficulty and expense of dioxin sampling and analysis.

between input PVC and output PCDD/PCDF and that it is purposeful to reduce chlorinated plastics inputs to incinerators."[225]

- German scientists have found that removing PVC sheathings from copper cables before they are recycled in copper smelters causes dioxin emissions to drop precipitously.[226]
- Four studies have found that the addition of PVC-containing "refuse-derived fuel" to incinerators burning salt-containing organic matter like wood chips or peat results in significant increases in dioxin formation.[227]
- According to a 2000 study by Japanese researchers, adding PVC to a mixture of chlorine-free matter in a pilot-scale incinerator increases dioxin emissions substantially; when more PVC is added, more dioxin is formed.[228]

In some of these studies, a relationship was seen in the air emissions but not in the fly ash, or vice versa, reinforcing the difficulty of establishing statistically significant relationships in the complex context of burning real wastes in large incinerators.

Two widely cited studies, one by the New York Department of Environmental Conservation[229] and the other by the European plastics industry,[230] have come to the opposite conclusion, finding no relationship of dioxin emissions at individual trash incinerators with PVC content of the waste burned. Neither of these investigations controlled or adjusted for other factors that affect dioxin formation, including facility type, operating conditions, or other characteristics of the waste feed. This oversight radically weakens any study's ability to detect a potential relationship between PVC and dioxin formation. Indeed, an EPA reanalysis of the data from the New York study found that when combustion conditions were adjusted for, emissions of dioxins and furans increased as PVC content of the waste rose.[231]

A recent Swedish investigation found that dioxin formation is directly related to chlorine content, but only when chlorine levels in the fuel exceed 0.5 percent, as they do in most modern waste streams. Changes in chlorine content below this level had no statistically significant effect on dioxin emissions.[232] These results could indicate that there is a threshold below which chlorine has no impact on dioxin levels, but it is equally possible that the failure to find a correlation at low chlorine levels is an artifact of the limits of chemical and statistical analysis: as levels of both chlorine and dioxin decrease, measurement error and statistical fluctuations become more and more important, swamping a fading signal under a growing chorus of noise.

Some studies indicate that burning large quantities of salt can produce dioxin. For instance, paper mills often burn logs that have been soaked in saltwater, and these incinerators have much higher concentrations of dioxin in their emissions than burning unsoaked wood.[233] The Swedish report discussed above found that it did not matter whether the chlorine came in organic or inorganic form—both gave rise

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[225] Wagner and Green 1993; this study also measured emissions of chlorophenols as a dioxin surrogate.
[226] Christmann et al. 1989.
[227] Vesterinen and Flyktmann 1996; Halonen et al. 1993; Hutoari and Vesterin 1996; Manninen et al. 1996. In all of these studies, dioxin levels in fly gas or flue gas increased with increasing feed of refuse-derived fuel to the burner, which was significantly higher in chlorine content than the organic matter used in comparison runs.
[228] Hatanaka et al. 2000.
[229] Visalli 1987.
[230] Mark 1994.
[231] EPA 1988.
[232] Wikstrom et al. 1996.
[233] Pandompatam et al. 1997.

to dioxin in approximately equal amounts.[234] One of the Japanese studies also found that burning large quantities of salt in a lab-scale incinerator could result in substantial dioxin emissions.[235] Another study found that burning PVC caused a much greater increase in dioxin formation than salt did, although the two substances caused similar increases in dioxin when municipal incinerator fly ash—which contains a wide range of organochlorines and other compounds—was included in the mix.[236]

These results conflict with the findings of the other studies discussed above, so the importance of salt in dioxin formation in incinerators remains an open question. From a policy perspective, however, it does not really matter how much dioxin salt combustion can produce. If burning chloride results in negligible dioxin emissions, then dioxin output depends almost entirely on the organochlorine content of the waste. Lowering the input of organochlorines is necessary to reduce the formation of dioxin. If, on the other hand, burning salt can produce dioxin in amounts comparably to the burning of PVC and other organochlorines, then dioxin generation depends on the waste's total level of chlorine (organic plus inorganic). Lowering the quantity of organochlorines in the waste will then reduce the total chlorine level and reduce dioxin formation. Either way, if we want to prevent dioxin formation in incinerators, we need to stop burning organochlorines.

Whatever the quantities, salts are ubiquitous in organic matter and cannot be removed easily from production, commerce, or the waste stream. In contrast, PVC use is highly preventable. Alternatives for most uses are currently available, ranging from traditional materials to chlorine-free polymers.[237] Any program to eliminate dioxin generation at the source should include provisions to reduce the use and combustion of PVC.

Vinyl Institute's ASME dioxin study

To rebut evidence linking incineration of vinyl to dioxin formation, the Vinyl Institute (VI) frequently cites a single study, purportedly by the American Society of Mechanical Engineers (ASME), a professional society representing 125,000 mechanical engineers worldwide, "[which] found little or no correlation between chlorine input and dioxin emissions from incinerators."[238] This study is deeply flawed for several reasons—and it does not provide an adequate basis to dismiss the many studies that do establish a link between dioxin generation and the combustion of PVC and other organochlorines.

ASME study is biased

Several vinyl industry documents shed light on the purpose and origins of the ASME report. Just before U.S. EPA released its draft Dioxin Reassessment in 1994, the Vinyl Institute commissioned the public relations firm Nichols-Desenhall Communications to prepare a *Crisis Management Plan for the Dioxin Reassessment*. According to the plan, "EPA will likely conclude that the incineration of chlorinated compounds is the single largest known contributor of dioxin…We believe that PVC will be specifically mentioned and potentially slated for further regulation.." In order to "prevent punitive regulation of PVC by EPA, Congress, or the state legislatures," the plan advised the Vinyl Institute how to present itself in the media and "strongly urge[d] VI to aggressively defend the industry's credibility through the use of third party sources to debunk…EPA's misleading claims."[239]

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[234] Wikstrom et al 1996.
[235] The report of Hatanaka et al. (2000) also found that NaCl and PVC resulted in similar increases in dioxin formation, although the unusually high concentration of NaCl added was thought to have resulted in less optimal combustion conditions, possibly increasing dioxin emissions indirectly.
[236] Takasuga et al. 2000.
[237] Thornton 2000.
[238] Burns 2000.
[239] Burnett 1994.

The industry took the advice of its public relations firm. In 1994, the Vinyl Institute's Incineration Task Force hired the consulting firm Rigo and Rigo, Inc. to prepare an "independent" analysis, which found that the amount of dioxin released by incinerators has no relation to the amount of chlorinated organic materials fed into them.[240] The Vinyl Institute arranged to have the report published as a product of the prestigious ASME, an independent professional organization. According to Vinyl Institute documents, one of the leaders of the Vinyl Institute's Incineration Task Force, Dick Magee, was also an active ASME member; Magee brokered an arrangement in which the Vinyl Institute would hire and fund Rigo to write a report that would be released under the ASME banner. According to an internal Vinyl Institute memo from 1994, the purpose of ASME's involvement was to create the illusion of "third-party" authority, and that the Rigo report was conceived, carried out, and rewarded in a spirit of public relations, not unbiased analysis. The memo reads:

> The Vinyl Institute has created an Incineration Task Force in anticipation of adverse EPA actions regarding dioxins and furans…Dick Magee brought forward a proposal from the American Society of Mechanical Engineers to hire Rigo & Rigo Associates, Inc., of Cleveland, OH. The purpose of ASME as the contractor is to provide unassailable objectivity to the study…
>
> The Incineration Task Group interviewed Dr. H. Gregory (Greg) Rigo, principal of Rigo & Rigo Associates, Inc. by phone and found him to be extremely knowledgeable about incineration and to have several proprietary databases VI had not discovered. He is also user friendly, i.e., willing to set his priorities to our needs, and appears to be sympathetic to Plastics, Vinyl, PVC, and Cl2…
>
> The ASME proposal calls for $130,000 for the Rigo & Rigo/ASME study. Since there are many unanswered questions regarding dioxins and since VI may want to use Greg Rigo as an expert witness or advocate to talk about the report, I am proposing an additional $20,000 as a contingency fund, for a total of $150,000 to be fully funded by VI.[241]

Methodological flaws

The methodology of the Rigo report is no less flawed than its origins, undermining the reliability of its claim that burning organochlorines is not related to dioxin formation. The study was not experimental, so it could not directly refute the existence of a chlorine-dioxin link. Instead of generating new data, the authors compiled existing trial burn measurements from a large number of incinerators, statistically analyzed the relationship between indicators of chlorine feed and dioxin releases, and concluded that there was no statistically significant relationship between the two. A statistical analysis of this type is particularly sensitive to design problems: if the putative cause and effect are not measured accurately, or if confounding factors are not taken into account, then a meaningful relationship is likely to go undetected. In fact, the study's data and methods on dioxin output and chlorine input were flawed in several ways, suggesting that its failure to detect a causal link is more likely an artifact of bad study design than a meaningful finding that no relationship between chlorine and dioxin actually exists:

1. The Rigo study failed to take account of differences among facilities. Chlorine input is not the only factor that determines the magnitude of dioxin emissions from incinerators; combustion conditions, the types and quantities of substances in the waste, and other variables also affect the amount of dioxin that will be released. Because of this complexity and constant fluctuations of many factors, statistical relationships between stack emissions and indicators of waste input or combustion conditions can seldom be established, even at individual incinerators.[242] Massively

[240] Rigo et al. 1995.
[241] Goodman 1994.
[242] Illustrating this point, even carbon dioxide, a widely accepted indicator of combustion conditions, is not consistently related to the emission of unburned wastes, according to Staley et al. 1986 and EPA 1990.

compounding this problem, Rigo used data from a large number of incinerators operating under widely variable conditions, but did not control or adjust for differences in facility type, operating parameters, waste type, or other factors. A statistical summary of data from many different facilities, with no attempt to control or adjust for confounding factors, cannot be expected to detect a signal within such extensive noise. Even a strong relationship between organochlorine input and dioxin output is likely to go undetected in a study designed in this manner.

2. The Rigo study also used data from unreliable sources. The emissions data in Rigo's analysis came almost exclusively from trial burns designed for permitting purposes, without the proper kinds of controls and measurements necessary to evaluate the relationship between chlorine input and output. Moreover, trial burn data are notoriously problematic. First, with their highly simplified designs, these traisl do not accurately represent the way incinerators operate in the real world, when waste composition and operating conditions constantly fluctate. Further, they do not measure the much larger quantity of chemicals that are released after the feed of waste to the incinerator has stopped.[243] In fact, many trial burns have conducted their evaluations of low- or no-chlorine wastes after chlorinated wastes have been burned, so the later stack samples become contaminated by continuing emissions from earlier runs. The use of results from trial burns of this sort thoroughly scrambles any relationship that might otherwise have been recognizable between chlorine input and dioxin input.

3. Rigo's study relied on the wrong kinds of measurements. To investigate a link between the amount of organochlorines burned and the amount of dioxin produced by incinerators, Rigo should have examined the statistical relationship between the mass of organochlorines fed to an incinerator and the mass of dioxins released. Instead, the study tracked "surrogate" measures for both of these parameters, measuring the *concentration* of hydrogen chloride (HCl; the primary by-product of organochlorine combustion) in the stack gas as a rough indicator for the mass of organochlorines in the feed; as a surrogate for the mass of dioxin released, it examined the concentrations of dioxin in the stack gas.[244] The problem is that concentrations do not accurately represent quantities, for several reasons:

   - If the total flow of stack gas increases (as it generally will if more waste, and thus more chlorine, is fed to the incinerator), the concentrations of dioxin in the gas may decrease, even if a larger amount of dioxin is being emitted.
   - Stack gas measurements omit pollutants directed into fly ash, bottom ash, and scrubber water, so changes in the efficiency of pollution control devices can reduce the concentration of dioxin in stack emissions while total dioxin formation increases. Control devices can also reduce the concentration of HCl while total organochlorine input rises. (Because pollution control devices have different capture efficiencies for dioxin and hydrochloric acid, the concentrations of these materials in the stack gas after it passes through this equipment will not reflect the ratios of the amounts that were actually produced by the incinerator).

[243] Licis and Mason 1989.

[244] Rigo analyzed Hydrogen chloride in stack gas for municipal and medical waste incinerators. For hazardous waste incinerators, his analysis was based on the percent chlorine in the waste feed, a parameter that also does not reflect the mass of chlorine. If the percent of chlorine stays the same and total waste feed is increased, then the mass of chlorine feed will increase but would not have been noted using Rigo's approach. Further, increasing the waste feed typically increases the stack gas flow rate, which will tend to reduce dioxin concentrations even if the mass of dioxin emitted increases.

- Hydrogen chloride is formed not only by the combustion of organochlorines but also by the burning of chloride salts. It is therefore not a reliable indicator of the amount of organochlorines fed to an incinerator.

The variables that Rigo analyzed are thus grossly inappropriate substitutes for the quantities that are truly of interest; Rigo's failure to find a relationship between the surrogates he used says nothing about whether a link actually exists between organochlorine input and dioxin generation.

All the flaws discussed above cripple the ASME study's ability to establish a link between chlorine and dioxin. A finding of "no relationship" is only as good as a study's power to detect a relationship, and in this case that power can only be described as pathetically weak. On the basis of Rigo's analysis, no reliable inferences can be drawn about whether a relationship exists between the amount of organochlorines burned and the amount of dioxin formed in an incinerator. With more than twenty well-designed studies coming to the opposite conclusion—that burning PVC and other organochlorines produces dioxins, and burning less reduces dioxins—Rigo's findings are far from persuasive. The weight of evidence from laboratory, pilot, and full-scale tests clearly establishes that vinyl is an important source of dioxin in incinerators, fires, and combustion-based recycling facilities, which together are responsible for the majority of identified dioxin releases in the world.

PVC and dioxin—historical evidence

The theory that burning organochlorines like PVC is an insignificant dioxin source and that salt is responsible for incinerator emissions of dioxin implies several specific predictions, none of which turn out to be true. First, if salt is a more important dioxin source than burning organochlorines, forest fires should result in large dioxin releases because plant matter is rich in salt. According to research by chemists at Indiana University, however, dioxin levels in the sediment of a U.S. lake, the watershed of which suffered a major forest fire in 1937, show no change whatsoever around or after the time of the fire.[245] More recently, scientists in Spain analyzed samples of salt-containing vegetation and soil that burned in four different 1998 forest fires; the burned materials showed no increase in dioxin levels compared to background levels, leading the researchers to conclude, "Natural fires seem not to be an important source of dioxin-like compounds."[246]

The second prediction implied by industry's salt theory is that historical levels of dioxin should track trends in the burning of salt, not the production and incineration of organochlorines—but they do precisely the reverse. Several studies have analyzed the dioxin and furan content of mummified and frozen remains of people who lived several hundred to several thousand years ago, including individuals from cultures that cooked over indoor fires and were exposed to considerable amounts of combustion emissions. These studies have found that dioxin levels (measured as TCDD-equivalents) in ancient tissues were no more than 1 to 2 percent of the amount found in modern humans, and even this amount could represent contaminants deposited in the samples in modern times, especially during handling and analysis.[247]

Dioxin levels in sediment cores from lakes and seas in North America and Europe also indicate that organochlorines and not the burning of salt are responsible for the bulk of dioxin emissions (figure 3). Every study conducted to date shows that dioxin levels were extremely low before the 20th century (when chlorine and organochlorine production began), despite the fact that natural and industrial combustion processes were abundant in this period. Sediments in Swedish lakes show no measurable

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[245] Brzuzy and Hites 1996b.
[246] Martinez et al. 2000.
[247] Schecter 1991;, Ligon et al. 1989; Schecter et al. 1988; Tong et al. 1990.

dioxin before 1945,[248] and those in the Great Lakes show none before 1920.[249] In the Baltic, dioxins and furans were present in a sediment sample dated to 1882, but the levels were 20 times lower than the peak concentrations in 1978.[250] A study of two lakes in Germany's Black Forest found that sediments from the seventeenth and eighteenth centuries contained small quantities of dioxins and furans—77 and 34 times lower than the maximum concentrations from this century. Expressed as TCDD-equivalents, the ratios were even higher: 310 and 90 times greater in modern than in pre-chlorine sediments.[251] In New York's Green Lake, small quantities of dioxins and furans are present in layers from the late 1800s, but at concentrations 1,500 times lower than those found in the 1960s.[252]

Only with the advent of chlorine chemistry and the incineration of its products and by-products did dioxin levels begin to rise. In all samples, dioxin concentrations began to increase slowly in the early decades of this century, then shot up rapidly from the 1940s to the 1970s—rising 25-fold or more between 1935 and 1970, then declining somewhat thereafter.[253] This pattern is consistent with the rise of chlorine chemistry, which peaked in the 1960s or 1970s, followed by restrictions on dioxin-contaminated pesticides and chlorinated gasoline additives went into effect.

Although these trends follow the production of chlorine, they do not even approximately track the history of combustion of salt, either industrial or natural. One study of dioxin trends in Great Lakes sediments found that dioxin levels do not follow trends in combustion of coal—practiced on a massive scale long before dioxin concentrations began to rise—but they do correspond closely to the rise of the chlorine chemical industry (figure 4). These results suggest that industrial combustion processes—including coal-fired power plants, furnaces for heating, rail engines, steel mills, and other industries powered by coal (which contains chloride salts)—have never been major sources of dioxin. The authors of the Great Lakes studies summarized their results so succinctly that they are worth quoting at length:

> There is an abrupt increase in PCDD and PCDF concentrations around 1940…Starting at this time, the production of chlorinated organic compounds such as chlorobenzenes and chlorophenols increased substantially. These compounds are used in a variety of products, including building supplies, herbicides, and packaging. Much of these materials eventually become incorporated in solid wastes. The trend for the production of chloro-organic compounds is similar to the sedimentary PCDD and PCDF profiles. The agreement between these two trends is convincing despite the uncertainties introduced by sediment mixing and the errors inherent in the dating and quantitation techniques…It is clear that the high levels of dioxins and furans found in presently accumulating sediments are not due to the advent of fire.[254]

If organochlorines have nothing to do with dioxin emissions, then why were dioxin levels in the environment non-existent or minuscule before the chemical industry began to produce them? In particular, why were dioxin levels so low during the 19th century when combustion of chloride-containing materials such as coal and wood was at its peak? These data make abundantly clear that the majority of dioxin in the environment is due to the production, use, and disposal of chlorine gas and organochlorines.

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[248] Reviewed in Alcock and Jones 1996.
[249] Czuczwa and Hites 1986; Czuczwa et al. 1984; Czuczwa and Hites 1985.
[250] Kjeller and Rappe 1995.
[251] Juutner et al. 1997.
[252] Reviewed in Alcock and Jones 1996. Echoing these findings, EPA scientists, in a study of 11 lakes in remote parts of the U.S., found that PCDD/F concentrations in pre-1930 sediments were at most one-tenth the levels in more recent layers (Cleverly et al. 1996).
[253] Brzuzy and Hites 1996b.
[254] Czuczwa and Hites 1984. Additional data are reported in Czuczwa and Hites 1986 and 1985.

In conclusion, while it is likely that some dioxin can be formed by the combustion of chloride-containing salts, the available evidence indicates that industrially-produced materials containing organochlorines—PVC in particular—are the dominant cause of dioxin generation in incinerators. More importantly, these materials are the most readily preventable cause of dioxin formation. Salts are naturally ubiquitous, but we can choose to stop producing, using, and burning organochlorines. As the Danish Technical Institute has written, "It is most likely that the reduction of the chlorine content of the waste can contribute to the reduction of the dioxin formation, even though the actual mechanism is not fully understood."[255]

PVC is the major chlorine source in the majority of the combustion facilities that dominate inventories of dioxin sources. The production and use of PVC also contributes to dioxin pollution. It therefore appears that PVC is responsible for more dioxin generation than any other single product. As more and more vinyl installed in buildings over the preceding decades enters the waste stream for disposal, the potential for dioxin generation grows accordingly. Any program to eliminate dioxin generation at the source—a public health imperative—should include provisions to reduce the use of PVC in applications susceptible to accidental fire or disposal by combustion.

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[255] DTI 1995.

Table 4 Inventoried dioxin sources in North America, Europe, and the world

	Percent of all releases from inventoried sources				
Source type	United States [1]	European Union[2]	United States [3]	Great Lakes[4]	World[5]
* Municipal waste incinerators	40.1	25.1	51.4	20.1	37.6
Ferrous metals production	NA	21.1	0.8	10.6	11.7
* Copper smelting	19.7	1.3	2.6	4.1	2.6
* Medical waste incinerators	17.4	14.2	10.3	48.7	2.8
Forest, brush, straw fires	7.6	NA	7.7	0	11.7
* Accidental fires	NA	6.6	3.7	NA	NA
Wood and coal combustion	6.0	17.1	5.9	4.4	NA
Hazardous waste incineration	5.7	0.6	2.6	8.0	22.7
Dioxin-contaminated chemicals	NA	6.6	4.7	NA	NA
* Uncontrolled trash incineration	NA	3.0	NA	NA	NA
Automobile fuels	1.4	1.9	0.4	1.4	0.4
Cement kilns (no hazardous waste)	0.6	0.4	NA	2.0	10.7

* Dioxin sources in which PVC is a major chlorine donor.
NA = quantitative estimate not available.
Note: There are numerous additional dioxin sources for which none of the inventories made a quantitative estimate, due to inadequate data. Sources are listed from largest to smallest, by the percent contribution in EPA's inventory, except for sources with NA in that column, which were ordered according to their contribution in the EU inventory. Sources with less than 1 percent contribution in all inventories are not shown.
1. Percent of all identified releases to air of PCDD/F (TEQ) based on median estimates for year 1995. Hazardous waste incineration estimate includes releases from cement kilns that burn hazardous wastes, as well as boilers and industrial furnaces.
2. Percent of all identified releases to air in the European Union.
3. Percent of identified emissions of total PCDD/F to the air in the United States as of 1989. Municipal waste incinerators includes apartment incinerators. Accidental fires include structural fires, PCB fires, and PCP fires.
4. Percent of identified emissions of PCDD/F (TEQ) to the air that reach the Great Lakes.
5. Percent of identified PCDD/F releases (TEQ) to the air. Estimate for hazardous waste incineration includes cement kilns burning hazardous waste; estimate for cement kilns does not. Estimate for forest, brush, straw fires includes all biomass combustion, including wood.
Source: U.S. EPA 1998; Hanberg et al. 1999; Thomas and Spiro 1995; Cohen et al. 1995; Brzuzy and Hites 1996a.

Table 5 Dioxins in ash from burning organochlorines and chloride-containing materials

Material	Total PCDD/F (ppt)	TEQ
Materials not known to contain organochlorines		
Writing paper	ND	ND
Wood	ND	ND
Cotton	ND	ND
Wool	ND	ND
Polyethylene	2.9	<0.1
Acrylonitrile-butadiene rubber	2	<0.1
Fir wood	21.4	0.65
Organochlorine plastics		
PVC plastic (pure)	244–2,067	3.2–42.2
PVC flooring material	352–1,847	8.2–14.5
PVC window frame material	7.5–969	8.8–18.1

PVC cables (copper)	669–2,670	11.4–52.6
PVC cables (no copper)	416–843	7.4–16.6
PVC gloves, hose, pipes, tape	158–954	2.5–16.5
PVDC plastic	3,304	14.1
Chloropolyethylene plastic	840	10
Polychlorobutadiene (neoprene) plastic	323–1,096	0.7–4.7
Materials containing other organochlorines		
Bleached coffee filters	6.3–7.7	0.15–0.23
Chloroparaffins	1,049	5.3
Dichloromethane	26,302	478
1,1,1-Trichloroethane	21,746	340
Tetrachloroethane	9,072	132
Trichloroethylene	120,915	149.5
Perchloroethylene	212	0.4
Epichlorohydrin	1,532	36
Chlorobenzene	16,135	0.5
p-Chloronitrobenzene	190,096	21.5
o-Chloronitrobenzene	32,293	216
p-Chlorotoluene	1,033	ND
2,4-D	178,016	361
Linuron pesticide	3,110	32

Source: Theisen 1991.

Figure 3 Dioxin deposition in European sediments

The vertical axis shows concentrations of total dioxins and furans (ppt) in sediment cores from the Baltic (circles) and two German lakes—the Wildsee (triangles) and the Herrenweiser See (squares), expressed as a percentage of the highest levels measured in each location. In all locations, levels were extremely low prior to the advent of chlorine chemistry, and they rise rapidly thereafter.

Source: Juttner et al 1997; Kjeller and Rappe 1995.

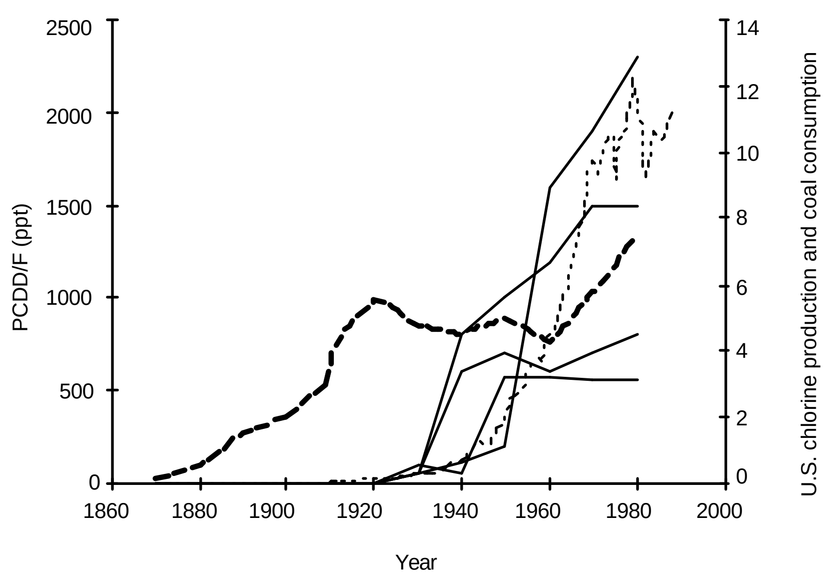

Figure 4 Dioxin deposition to Great Lakes sediments

Solid lines show levels of total dioxins and furans in four sediment cores from Lake Huron; the thin dotted line shows U.S. chlorine production capacity (in millions of short tons per year); the thick dashed line shows U.S. coal combustion (in 100 millions of short tons per year). Dioxin levels were low or zero when coal combustion was at its peak, increasing only with the growth of chlorine chemistry.

Source: Dioxin and coal redrawn from Czuczwa and Hites 1984; chlorine from Chlorine Institute 1991, Leder et al 1994.

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5. BACKGROUND ON PERSISTENT ORGANIC POLLUTANTS (POPS)

In recent years, there has been extensive scientific and political activity on toxic pollutants, their global distribution, and their effects on highly exposed populations and the general public. An understanding of that context strengthens the case for action to restrict PVC in building applications, and action on PVC would in turn strengthen international efforts to reduce persistent toxic pollution at the source.

GLOBAL DISTRIBUTION OF POPS

Recently the first global agreement to eliminate sources of persistent organic pollutants (POPs) has been negotiated. The POPs treaty is, in large part, a response to scientific research in the past decade that has identified a variety of synthetic chemical pollutants that are now globally distributed in the environment and food web, have damaged wildlife populations, and may have caused large-scale human health damage.[256] Global contamination has occurred because many synthetic chemicals are persistent in the environment, resisting natural degradation processes for months, years, or even decades. As a result, even substances that are discharged at a relatively slow rate build up to higher levels over time and are distributed widely by air and water. Because many synthetic organic substances are derived from petrochemicals, they are oil soluble and therefore bioaccumulate—they build up in the fatty tissues of living things and multiply in concentration as they move up the food chain. Some bioaccumulative substances reach concentrations tens of millions of times greater than their levels in the ambient environment in species high on the food web, including humans.[257]

Releases of persistent and/or bioaccumulative substances since the expansion of synthetic chemical manufacturing after World War II has resulted in the global accumulation of POPs in areas remote from any known sources of these substances, including the high Arctic,[258] the isolated rainforests of South America and Africa,[259] and remote regions of the deep oceans.[260] In the Arctic, where long residence times, cold temperatures, and long food chains combine to enhance the persistence and bioaccumulation of organic chemicals, body burdens of humans and wildlife are as much as an order of magnitude greater than in temperate latitudes of industrialized nations.[261]

Although research and policy have focused primarily on a handful of substances—dioxins, PCBs, and about a dozen organochlorine pesticides—global contamination cannot be reduced to a few "bad actors." In the Great Lakes, 362 synthetic chemicals have been "unequivocally identified" in the water, sediments, and food chain. The list includes the infamous POPs, but it also contains a full spectrum of less familiar substances, from solvents and chemical intermediates to a host of complex industrial specialty chemicals, by-products, and breakdown products.[262] By-products of chlorinated chemical manufacture and disposal are present in measurable quantities in the Canadian Arctic[263] and over the remote Atlantic Ocean,[264] and a variety of chlorinated benzenes are components of rain and snow.[265]

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[256] Thornton 2000; Colborn et al. 1996.
[257] Tatsukawa and Tanabe 1990; Allan et al. 1991.
[258] Gregor and Gummer 1989; Patton et al. 1991; Barrie et al. 1997.
[259] Simonich and Hites 1995.
[260] Ono et al. 1987.
[261] Dewailly et al. 1993; Norstrom et al. 1990.
[262] Great Lakes Water Quality Board 1987.
[263] Barrie et al. 1997.
[264] Fuhrer and Ballschmitter 1998.
[265] Brun et al. 1991.

Chlorinated solvents, refrigerants, and their environmental degradation products have become truly ubiquitous contaminants of the atmosphere and vegetation.[266]

With the environment and food web ubiquitously contaminated, it should come as no surprise that people are contaminated as well. Human exposures come through inhalation, drinking water, and eating food. For highly bioaccumulative substances, the vast majority of the average individual's exposure—in excess of 90 percent—comes through the food supply, primarily from animal products.[267] At least 700 xenobiotic organic chemicals are present in the adipose tissues of the general population of the United States.[268] Close to 200 organochlorine by-products, metabolites, pesticides, plastic feedstocks, solvents, and specialty chemicals have been specifically identified in the blood, breath, fat, milk, semen, or urine of the general U.S. and Canadian populations—people with no special workplace or local exposures to these substances. Fat-soluble chemicals that have accumulated in a woman's body easily cross the placenta and are concentrated in breast milk.

The now-ubiquitous global presence of synthetic chemicals—in large-scale production for just over than half a century—supports a simple inference: substances that persist or bioaccumulate cannot be integrated into natural cycles. Discharged in even small amounts, these chemicals build up gradually in the environment and in living things. Given enough time, even small "acceptable" discharges reach unacceptable levels. The ecosystem's assimilative capacity for persistent or bioaccumulative substances is therefore zero, and the only "acceptable" discharge is also zero. Any amount greater than zero must be expected to lead to some degree of long-term, large-scale contamination. For this reason, strategies designed to eliminate the materials and processes that produce persistent or bioaccumulative substances are far superior to those that attempt to control, manage, or dispose of persistent chemicals after they have been produced.

ENDOCRINE DISRUPTION

What are the impacts of universal exposure to POPs on the health of people and wildlife? Important discoveries have emerged in the past decade from toxicology, epidemiology, and ecoepidemiology on the hazards of low-dose exposure. Traditionally, toxicological studies have focused on frank manifestations of toxicity at relatively high doses, such as cancer, organ damage, paralysis and tremors, structural birth defects, and death. Recently, however, it has been discovered that many synthetic chemicals can, at minute doses, result in subtle but significant deficits in an organism's functional capacities, such as fertility, immunity, cognition and intelligence.

Many of these effects occur as the consequence of a newly recognized set of toxicological mechanisms—disruption of the body's endocrine system.[269] The endocrine system comprises the hormones, the glands that produce them, and the response of diverse tissues to these substances. Hormones are the body's natural signaling molecules, circulating in the blood in low concentrations (typically in the ppt range) and triggering cascades of gene expression that control essential aspects of development, behavior, immunity, reproduction, and the maintenance of homeostasis.

In the past decade, a flurry of research has identified dozens of industrial and agricultural chemicals that disrupt the endocrine system. Some mimic or block the activity of the body's endogenous hormones by interacting directly with the hormone receptor molecules mediating the response of cells to hormones—such as the steroids estrogen, testosterone, progesterone, and the stress hormones cortisol.

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266. DeLorey et al. 1998; Makhijani and Gurney 1995; Plumacher and Schroder 1993.
267. EPA 2000a.
268. Onstot et al. 1987.
269 National Research Council 2000; Guillette and Crain 1999.

Others change the rate at which the body produces or excretes its own hormones, causing unnaturally low or high levels of steroid, retinoid, and thyroid hormones. Still others disrupt local signaling mechanisms that are critical to development, brain function, and the immune response, including growth factors, neurotransmitters (molecules that mediate communication among brain cells), and cytokines (intercellular signaling molecules that regulate immune function).

The U.S. National Academy of Sciences has reviewed the evidence on endocrine disruption and concluded that adverse developmental, immunological, neurological, and reproductive effects have occurred in human populations, wildlife, and laboratory animals as a consequence of exposure to hormonally active compounds found in the environment.[270] According to the Academy, effects observed include functional and structural abnormalities of the reproductive tract, reduced fertility, behavioral changes, reduced cognitive ability, and immune suppression. Many studies of wildlife have shown associations between health impacts and exposure to endocrine disrupting substances, including in large ecosystems like the Great Lakes and Baltic Sea with pollutant concentrations that are increased above universal levels by less than an order of magnitude. There is evidence that the health of the general public may have been compromised by universal exposure to these substances, but the Academy did not reach consensus on this point. The panel noted that the degree of support for this hypothesis depends on perspectives that are informed by values, including the standard of proof that should be satisfied before conclusions about public health are drawn, what kinds of effects are worthy of concern, and how scientific findings about effects on one species or stage of life should be extrapolated to others.

DIOXIN AND RELATED COMPOUNDS

Occurrence and exposure

The most intense scientific activity has focused on 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, also known colloquially as dioxin) and other structurally similar compounds that act through a similar toxicological mechanism (called, collectively, dioxin-like compounds). Research on dioxins is particularly relevant to the PVC debate because of the evidence that the PVC lifecycle is a major source of dioxins.

Dioxins are extremely persistent substances that break down slowly if at all in the environment. Dioxins are also powerfully bioaccumulative and are now globally distributed in the ambient environment and food web. They can be detected in the tissues and fluids of the entire U.S. population. They are cleared from the body extremely slowly: U.S. EPA estimates an average half-life for TCDD in humans of more than 7 years; the body burden of the average adult therefore increases throughout life as the substance gradually accumulates in fatty tissues. Dioxins are passed transgenerationally with great efficiency; a typical nursing infant in the United States receives a daily dioxin dose 92 times greater than that of the average adult.[271]

Health impacts of dioxin

In 2000, U.S. EPA released its Dioxin Reassessment,[272] a comprehensive scientific summary and analysis of research in dioxin toxicology and epidemiology, and has come to the following conclusions:

- Epidemiological and laboratory studies have established that dioxin is a human carcinogen, echoing the findings of both the U.S. National Toxicology Program and the International Agency for Research

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[270] National Research Council 2000.
[271] EPA 2000a.
[272] EPA 2000a.

on Cancer.[273] Dioxin is the most potent synthetic carcinogen ever tested, causing increases in specific cancers and cancers of all sites at extremely low doses. In utero exposure to small quantities of dioxin are associated with increased cancer of hormone-responsive organs (such as mammary glands) when the exposed animal reaches adulthood.

- The general public's exposures to dioxin pose a calculated cancer risk in the range of one per 100 to one per 1,000—at least 1,000 times greater than the usual acceptable risk.[274] People who eat greater than average quantities of meat or fish are subject to even higher cancer risks. (EPA's estimates are based on numerous assumptions and may or may not accurately reflect actual risks.)
- Dioxin's non-cancer effects may be of even greater concern than its carcinogenicity. Dioxin is a potent endocrine-disrupting substance, interacting with an intracellular receptor and disrupting the action of gonadotropins, retinoic acid, steroid hormones, thyroid hormone, and growth factors at extremely low doses. Exposure to even a single tiny dose before birth can lead to profound effects on development of the brain and reproductive system, with effects including impaired cognitive ability and IQ, reduced sperm density, smaller or malformed reproductive organs and structures, and impaired sexual behavior.
- Dioxin is a powerful immune suppressant, interfering with immune function and increasing susceptibility to infectious disease at extremely low doses.
- The current body burden of the general human population is already at or near the level at which dioxin has been found to cause a variety of effects in laboratory animals and human populations, including cognitive defects, endometriosis, hormonal changes, immune suppression, reduced sperm count, and impaired development of the male and female reproductive systems.[275]
- There is no evidence of a threshold dose of dioxin below which no adverse health impacts occur. For all responses that have been studied—including expression of target genes, growth of pre-malignant liver tumors, and changes in circulating levels of thyroid hormones—the best estimate of dose-response relationships at low levels of dioxin is that the severity of the impact is roughly proportional to the magnitude of dioxin exposure.[276]

Supporting the view that there is no practical threshold for dioxin toxicity, several studies have discovered that almost infinitesimally low doses have significant biological effects. For example, when rats are given a single dose of TCDD as low as 64 billionths of the animal's body weight on day 15 of pregnancy, the behavior, function, and sexual development of their male offspring are compromised.[277] Dioxin's immunotoxicity has been documented at even lower levels. Doses of TCDD as low as 2.5 parts per quadrillion—equivalent to a mere 10 molecules per cell—completely abolish the ability of cultured immune cells to respond to signals to proliferate and mount an immune defense.[278] In whole animals, dioxin produces immunotoxicity at concentrations in the spleen about five times lower than this—on the

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[273] McGregor et al. 1998; National Toxicology Program 2001.
[274] Following EPA's usual approach, this risk estimate is based on the upper bound of the 95 percent confidence interval for the carcinogenic potency of dioxin. The potency is derived from both human and animal studies.
[275] See discussion in EPA 2000a, as well as DeVito et al. 1995 and Tryphonas 1995.
[276] See also Tritscher et al. 1994; Kohn et al. 1996; Portier et al. 1996.
[277] Peterson et al. 1992.
[278] Neubert and colleagues (1991) documented this effect in primate lymphocytes at TCDD concentrations as low as 10^{-14} moles per liter.

order of just two molecules per cell.[279] If there is a threshold for dioxin, it is so low that it is irrelevant for the purposes of environmental policy and health protection.

In addition to these findings, evidence from wildlife suggests a significant current environmental health hazard from dioxin contamination. A large number of ecoepidemiological studies have established that bioaccumulated dioxin-like compounds have caused large-scale epidemics of developmental impairment, endocrine disruption, immune suppression, and reduced fertility in mammals, fish, and birds in the Baltic Sea, the Great Lakes, and the Wadden Sea.[280]

Together, these findings indicate that we cannot assume that the general public has any margin of safety for dioxin exposure. Indeed, it is possible—though not proven—that dioxin-like compounds already contribute to society-wide rates of cancer, endometriosis, immune suppression, impaired cognitive development, and infertility. From a public health perspective, universal dioxin exposure is already too high by a considerable margin. Further releases of dioxins into the environment should be eliminated wherever technically feasible.

Trends in dioxin contamination

Trends in dioxin levels in the environment support the conclusion that measures to reduce dioxin generation through material substitution can effectively reduce contamination and human exposure. Numerous studies of soils and sediment in Europe and North America show that dioxin levels were very low before the 20th century (figure 3). They began to rise slowly around the turn of the century and then increased rapidly from 1940 to 1970, the period during which the chlorine industry expanded most rapidly.[281] Then, during the 1970s, many governments restricted the use of leaded gasoline (which contains chlorinated additives and thus produces dioxin when burned) and major applications of some dioxin-contaminated pesticides, including 2,4,5-T and pentachlorophenol. In the same period, the U.S. Clean Air Act and similar legislation in other nations required a wide range of industrial facilities (such as chemical plants, incinerators, and steel mills) to install particulate-reducing pollution control devices, which are likely to have reduced dioxin emissions to the air, as well. Following those actions, dioxin releases to the air—as measured by dioxin accumulation in plant foliage[282]—declined by nearly 80 percent between the late 1970s and the early 1990s. As one might expect, dioxin levels in the milk of cows, which eat foliage, subsequently declined, falling by about 25 percent between 1990 to 1994.[283] Because annual sediment layers primarily reflect the deposition of dioxin from the air into surface waters, dioxin concentrations in most samples of marine and freshwater sediment also declined.[284]

But declining deposition rates do not necessarily mean a lower total burden of pollutants in the environment. Sediment layers provide a reasonably reliable record of the quantity of a substance that settles to the bottom of a body of water in any year, which roughly indicates the amount that entered the water in that year. The annual flux of persistent compounds, however, is not directly related to the total environmental burden; if the rate at which one puts marbles into a jar declines from 100 per year to 50, the total number of marbles in the jar will continue to increase. For a record of the total amount of dioxin

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[279] Kerkvliet (1994) reports that TCDD concentrations in the spleen as low as 2 x 10^{-15} moles per liter caused immunotoxicity in laboratory rats.

[280] See for example Olsson et al. 1994. Reijnders 1986; de Swart et al. 1996; Giesy et al. 1994a and 1994b.

[281] Alcock and Jones (1996) provide an excellent review of dioxin trends. Specific papers include Czuczwa and Hites 1984, 1985 and 1986, Czucwa et al. 1984, Juttner et al. 1997, Kjeller and Rappe 1995, Kjeller et al. 1991, and Kjeller et al. 1996.

[282] Kjeller et al. 1996.

[283] Reviewed in Alcock and Jones 1996.

[284]. Sediment cores from two Black Forest lakes, for example, show a contradictory pattern. One shows that dioxin levels in the layer dated 1985–1992 were lower than in that from the period 1964–1985. The other, however, shows that dioxin levels in 1982–1992 were higher than in 1960-1982. (Juttner et al. 1997).

that has accumulated in the environment over time, soils are better indicators than sediments, because pollutants from the recent and the distant past stay near the top of the soil, rather than being buried in annual layers. British scientists have found that dioxin levels in soil, unlike those in sediments and foliage, continued to increase without interruption right through the 1980s and into the early 1990s. They concluded, "PCDD/Fs are persistent in soils, such that declines in atmospheric deposition may not result in a decline in the UK PCDD/F burden for some time. It may be that even with the anticipated declines in the primary emissions of PCDD/Fs over the next decade, the rate of deposition may still exceed the rate of loss from soils."[285]

Human and wildlife tissues reflect the same pattern, with a delay because of the persistence of these compounds in our bodies. Dioxin levels in several species of wildlife in the Great Lakes declined during the late 1970s, 1980s, and early 1990s.[286] By 1993, however, levels of dioxins in the eggs of Great Lakes trout had stopped falling, reaching, in the words of one group of researchers, "a steady state or a very slow decline."[287] No human tissue analyses are available from the early decades of this century, but dioxin levels in people from the United States increased steadily during the 1960s. Following the regulatory actions of the 1970s, levels declined during the 1980s.[288] Concentrations continued to fall in most European nations during the 1990s, although the data for the United States are ambiguous.[289]

There are no reliable projections of future trends in dioxin levels. Apparently, the successful actions of the past have had their effect, however. According to Swedish scientists, the declines are history, not a continuing trend. "During the last twenty years an overall decrease in the levels [of dioxin in human tissues] is recorded. The major part of this decrease dates back to the late 1970s and the early 1980s. The situation of today seems to be quite constant and resembles what has been found for PCB. Analyses of human breast milk show a similar trend."[290] In Germany, dioxin levels in human milk have stopped falling and increased slightly in the late 1990s.[291]

All this information suggests a pattern with clear implications for policy. Action to reduce production and use of dioxin-generating substances has reduced emissions to the environment of these compounds. On local and regional scales, contamination of the environment and the tissues of living organisms has fallen in response, with the speed of the decline varying among different kinds of sampled material. But these pollutants are so persistent that, so long as releases continue somewhere, the global environmental burden of these compounds declines slowly, if at all. If we allow releases to continue at a reduced rate, concentrations will stop declining when a new steady state is reached. If we want to reduce human and wildlife exposure, we should reduce the use of dioxin-generating materials rapidly. Because infinitesimal doses of dioxin are enough to cause health damage, the only level of dioxin exposure that should be considered acceptable from a public health perspective is zero. If we want to prevent the accumulation of dioxins and other persistent toxic chemicals in the global environment, we need to stop environmental releases altogether.

PHTHALATES

Usage

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[285] Alcock and Jones 1996. Kjeller et al. 1991 also provide a useful discussion.
[286] Allan et al. 1991. Alcock and Jones (1996) also review studies that suggest a decline in PCDD/Fs in Baltic wildlife during the same period.
[287] Huestis et al. 1997.
[288] Stanley et al. 1990.
[289] LaKind et al. 2001
[290] Johansson 1993.
[291] Furst 2000.

Concern has recently focused on phthalates, a class of compounds used as plasticizers in flexible PVC. Phthalates are organic chemicals used to make vinyl plastic flexible, and they can make up a large portion—up to 60 percent by weight—of the final product.[292] Flexible PVC—including flooring and wall coverings—accounts for just more than half of all vinyl demand, while the remainder is rigid, unplasticized materials like pipes and siding.[293] PVC accounts for the vast majority of all phthalate consumption, and phthalates are the dominant class of plasticizers used in soft vinyl products.[294] An estimated 50 percent of all phthalates produced are used in building and interior materials.[295] About 5.4 million tons of phthalates are used in vinyl products worldwide each year.[296] Vinyl is the only major plastic that requires phthalates to be flexible.

Four specific phthalates are used extensively in PVC and are relevant to this discussion: diethylhexyl phthalate (DEHP; U.S. production near 2 million tons per year), diisononyl phhalate (DINP; 178,000 tons per year), butylbenzyl phthalate (BBP; production not reported), and diisodecyl phthalate (DIDP; 135,000 tons per year). In addition, di-n-octyl phthalate is formed as a by-product of the production of other phthalates that are used in PVC and is released to the environment during the manufacture and use of flexible PVC.[297] The other commercially important phthalates dibutyl phthalate (DBP) and dioctyl phthalate (DOP) are not used appreciably in PVC.

Fate, occurrence, and exposure

Phthalates are moderately persistent in the environment. They can be degraded biologically or chemically in the presence of air in days or weeks; in anaerobic conditions, like those often found in groundwater, little if any degradation occurs, with a hydrolysis half-life of 2000 years.[298] Because phthalates are soluble in fat, they quickly adsorb into sediments or enter the food chain, where they can bioaccumulate.[299] Although some phthalates are partially metabolized in humans, DEHP tends to bioaccumulate in aquatic invertebrates and fish. Bioconcentration factors measured in fish range from 42 to 2680, indicating that fish swimming in water contaminated with DEHP accumulate in their tissues levels of DEHP that are up to thousands of times greater than the concentration in the water.[300]

Because of this behavior and the large quantities produced, phthalates have become ubiquitous environmental contaminants, present in air, water, fish, and human tissues on a global basis.[301] Because most phthalates are more soluble in fat than air or water, levels in outdoor air and water are typically low, although considerably higher levels of some phthalates occur in indoor air;[302] levels of DEHP and metabolites in animal and human tissues can be quite high, reaching concentrations higher than such infamous pollutants as PCBs and DDT.[303]

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[292] DTI 1995.
[293] These figures are for Western Europe (European Commission 2000).
[294] DTI 1995.
[295] Oie et al. 1997.
[296] My calculations are extrapolated from the figures for Sweden, where the phthalate input into PVC equals 22.6 percent (TNO Centre for Technology and Policy Studies 1996), assuming 24 million tons of vinyl produced per year worldwide.
[297] National Toxicology Program 2000.
[298] HSDB 1997.
[299] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a, 2000b, and 2000c.
[300] HSDB 1997.
[301] Giam et al. 1978;, Blount et al. 2000; HSDB 1997.
[302] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[303] Giam et al. 1978; National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.

For the general population, the greatest exposures to phthalates come through the food supply, with the highest levels in fatty foods like dairy, fish, meat, and oils, although indoor air contributes substantially as well.[304] Because of their higher rate of food consumption per kilogram of body weight, children ages 6 months to 4 years receive the highest exposures to phthalates, with a daily dose of DEHP (19 micrograms per kilogram of body weight) that is more than three times that of the average adult.[305] A recent U.S. Centers for Disease Control study analyzed urine samples from the general U.S. population and found surprisingly high levels of metabolites of BBP, DEHP, DINP, and DnOP (137, 21.5, 7.3, and 2.3 ppb, respectively), reflecting "considerable exposure" to these compounds, as well as other phthalates.[306] Because phthalates are fat-soluble, they cross the placenta easily and concentrate in breast milk.[307] The authors of the CDC study concluded, "Some individual exposures are substantially higher than previously estimated for the general population," and these "data indicate a substantial internal human dose of DBP, DEP, and BBP, [the metabolites of which] are of particular concern because of their developmental and reproductive toxicity in animals."[308]

Health impacts

Phthalates are well-recognized developmental and reproductive toxicants. DEHP is the most studied member of the class, and in studies of a variety of species of laboratory animals, relatively high doses of DEHP produce structural birth defects, developmental delay, and intrauterine death. DEHP also reduces estrogen levels, fertility, and ovarian weight, and it suppresses ovulation in female rodents. In males, DEHP causes testicular lesions, reduced androgen levels, and atrophy of the testes. Exposure in utero or during childhood is particularly problematic—developmental effects occur at doses up to 100 times lower than those that produce reproductive toxicity in the adult.[309] Exposure of a pregnant mother rat to DBP or DEHP disrupts the development of her male offspring's reproductive system; effects include reduced synthesis of testosterone by the fetal testis, loss of sperm-producing cells, and abnormal development of the testes, epididymes, and prostate.[310] Extremely low levels of MEHP (100 nanomolar, or less than 30 ppb) —approximately the same level as found in the urine of the general U.S. population[311]—cause significant damage to cultured sperm-producing cells of developing rat testes.[312]

The general human population is exposed to levels of DEHP that justify public health concern. EPA's reference dose (RfD) for DEHP is 20 micrograms per kilogram of body-weight per day.[313] An RfD is the "acceptable" exposure level, predicted by EPA based on toxicological studies, at which significant risk of health effects will not occur. But the average daily dose in the United States for children ages 6 months to 4 is 19 micrograms per kilogram of body weight, approximately the same as EPA's RfD.[314] And researchers at the Centers for Disease Control have estimated that the daily DEHP exposure of adults in the general U.S. population, based on the 95th percentile and maximal levels found in the general population's urine, is as high as 3.6 and 46 micrograms per kilogram per day—in the same range as EPA's RfD, and considerably higher for some individuals.[315]

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[304] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[305] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[306] Blount et al. 2000.
[307] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[308] Blount et al. 2000.
[309] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[310] Gray et al. 1999; Lambright et al. 2000.
[311] Blount et al. 2000.
[312] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[313] EPA 2000b.
[314] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[315] Kohn et al. 2000. The median exposure level was estimated to be 0.71 micrograms per kilogram per day.

These results make clear that the general public's DEHP exposure allows little or no clear margin of safety. Furthermore, EPA's RfD for DEHP was established in 1986 based on a 1953 study that examined changes in liver weight in rodents exposed to DEHP, supplemented by other studies from 1982 and 1984. This RfD was calculated before any of the relevant studies of the effects of chronic low-level exposure to DEHP and metabolites on reproduction and development were published. Since these types of impacts may occur at substantially lower doses than liver damage, even the RfD may not represent a truly safe dose.[316] It is therefore prudent from a public health perspective to reduce exposures to DEHP as rapidly as possible.

Considerably less research has been conducted on the toxicity of other phthalates, but some data are available. Like DEHP, BBP is a male reproductive toxicant, causing testicular lesions, reduced sperm counts, and increased infertility at relatively high doses in adult males—but virtually no data are available on impacts on the development of the reproductive system.[317] Monobutyl phthalate, a metabolite of BBP, causes cryptorchidism (failure of the testes to descend) when exposure occurs in utero.[318] Much more data needs to be gathered before the full suite of effects caused by each phthalate, together with the dose required to produce these effects at different stages of development, will be understood.

In 2000, an expert committee convened by the National Toxicology Program reported its review of the evidence on the reproductive and developmental toxicity of phthalates. The panel compared the doses of DEHP that produce developmental toxicity in animals to the levels to which infants and toddlers in the general U.S. population are routinely exposed, and concluded a "concern that exposure may adversely affect male reproductive tract development."[319] The panel also examined exposure that occurs across the placenta and via breast milk and concluded, "The panel has concern that ambient oral DEHP exposures to pregnant or lactating women may adversely affect the development of their offspring." Based on the available data, the panel expressed low, minimal, or negligible concern about other phthalates.

There are few epidemiological data concerning the impacts of phthalates on human development and reproduction. One study suggests that phthalate exposure of the general population may be related to endocrine disruption and altered reproductive development in girls. In Puerto Rico, the incidence of premature breast development (early thelarche, defined as breast development during the period from 2 to 8 years of age) is quite high (about 1 percent of the population) and has been rising rapidly in recent decades. This phenomenon cannot be explained by changes in nutrition or exposure to hormones used in agriculture,[320] and a similar trend has been documented in the United States.[321] Exposure to endocrine-disrupting compounds is one plausible explanation, because estrogens trigger breast development in girls. A case-control study of girls from the general Puerto Rican population found that the levels of phthalates in the blood of girls with premature breast development were 5.9 times higher levels than in girls without premature development. Levels of DEHP, which accounted for more than 80 percent of the total phthalates measured in the girls' blood, were 6.4 times higher among girls with premature thelarche. This study does not prove that phthalates caused the precocious sexual development, but, as the authors concluded, it suggests that the estrogenic or other endocrine-disrupting effects of phthalates may have contributed to the epidemic of early thelarche.[322]

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[316] EPA 2000b.
[317] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000b.
[318] Imajima et al. 1997.
[319] National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
[320] Colon et al. 2000.
[321] Hermann-Giddens et al. 1997.
[322] Colon et al. 2000.

Some phthalates may be carcinogens. According to the National Toxicology Program (NTP), DEHP is "reasonably anticipated to be a human carcinogen" based on consistent findings of liver cancer in laboratory animals. There has been some debate about whether the mechanism of carcinogenicity in rodents is relevant to humans. Based on this issue, the International Agency for Research on Cancer now lists DEHP as an animal carcinogen but as unclassifiable with regard to human carcinogenicity. But the NTP has not adopted this view, and scientists at the National Institute for Environmental Health Scientists have criticized the IARC's action as lacking a sound scientific basis in current understanding of DEHP's mechanism of toxicity.[323]

TRENDS IN PVC MARKETS

Polyvinyl chloride plastic was first marketed in 1936[324] but did not begin to play a major role in building construction until the 1950s. Production grew rapidly from the 1960s through the 1980s, and has now reached more than 30 million tons per year. This estimate includes the non-PVC components of vinyl products, such as plasticizers and stabilizers; production of pure polyvinyl chloride is now estimated at approximately 24 million metric tons per year worldwide.[325] Vinyl is the largest use of chlorine in the world, accounting for more than 40 percent of all chlorine use in the United States, with a similar or slightly greater proportion globally.[326]

Few materials have infiltrated modern life as ubiquitously as PVC, and construction represents the largest sector of vinyl applications. In the past fifty years, vinyl—the only major plastic that contains chlorine—has taken the place of ceramics, metals, textiles, and wood in a range of building products, including exterior siding, floor tiles, pipes, wall coverings, window frames, and wire and cable sheathings. PVC is also used in appliance casings, furniture, shower curtains, toys, upholstery, and other household items, as well as in automobile and other vehicle components, medical devices, office supplies, and packaging.

Today, PVC is not only the largest but also the fastest growing use of chlorine in the world. In fact, it is the only major chlorine application still increasing in the world's wealthy nations, and it is growing particularly rapidly in developing countries.[327] The reasons for the industry's aggressive expansion of PVC markets lie in the economics of the production of chlorine and its coproduct, sodium hydroxide (caustic soda or alkali). Alkali is a profitable and environmentally unproblematic substance that is used as a source of sodium and hydroxide ions in a wide variety of industries. The majority of the world's alkali is produced by chlor-alkali electrolysis, in which chlorine and sodium hydroxide are produced together in a fixed ratio. Chlorine is a hazardous gas, so it cannot be safely stored; the chemical industry therefore can only produce as much alkali as there are markets for chlorine. In recent years, as numerous uses of chlorine (for example, pulp and paper, refrigerants, and solvents) have been restricted for environmental reasons, a chlor-alkali imbalance has developed, requiring the industry to create new markets for chlorine in order to continue potential sales in alkali markets.[328] According to an analyst for the chlor-alkali manufacturer Elf-Atochem, "There is a logical progression toward permanent imbalance

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323 Melnick 2001.
324 Taylor 1957; Aftalion 1991.
325 Kielhorn et al. (2000) report global vinyl chloride production capacity of 27 million tons per year. Assuming 95 percent utilization of VCM in PVC and 95 percent operating rates, global PVC production is likely to be about 24 million tons per year.
326 Leder et al. 1994.
327 Growth is expected in a few much smaller applications, such as phosgene for polycarbonate and propylene chlorohydrin for propylene oxide, but the increases in these chlorine uses are less than one-tenth the growth expected in PVC (Mears 1995).
328 Leder et al. 1994.

between caustic supply and demand. Domestic chlorine consumption and chlorinated exports will set operating rates for U.S. chlor-alkali capacity, with the EDC/VCM/PVC chain leading the way."[329]

The industry's strategy to rectify the chlor-alkali imbalance is the aggressive expansion of markets for PVC and the feedstocks from which it is made—already the major global sinks for chlorine. For the past several decades, PVC production and consumption has grown at a remarkable pace, but recently PVC markets in industrialized nations have neared saturation. Vinyl has already replaced so many traditional materials, that growth in vinyl in these countries is now no greater than annual increases in gross national product.[330] This rate of growth is not nearly enough to offset the loss of chlorine demand in sectors that have been restricted so the industry has focused on expanding exports of PVC and its feedstocks to developing nations.[331] U.S. net exports of EDC, PVC, and VCM now contain about two million tons of chlorine per year—more than 15 percent of total chlorine production—and were expected to grow by a stunning 14 percent in 1998 alone.[332] The major recipients are Latin America and Asia, where PVC consumption is expected to grow at annual rates of 7 percent or more per year, leading to a doubling of demand each decade.[333] Why these countries? As an executive of a major Japanese PVC company explained, vinyl is a uniquely marketable product for export because poor countries need to reach only minimal levels of economic and technological development before they can be encouraged to buy plastic, and these nations usually have few environmental regulations:

> "Demand for PVC in the high-population developing countries will grow rapidly after their GNP per capita reaches $500 per year. On the other hand, in the world's major industrialized countries where per capita GNP is over $10,000/year, the use of PVC has come close to its maturity, and the growth rate of PVC may not be as much as the GNP growth rate. The concern about the disposal of waste material is one of the reasons for advanced society to refrain from excessive use of plastics."[334]

The rapid increase in vinyl consumption in developing countries means that, despite slow growth in PVC consumption in the wealthy nations, global demand for PVC will rise from 22 million tons per year in 1996 to 28 million tons per year 2000—an annual growth rate of more than 6 percent.[335] According to one industry analyst,

> "The most important structural changes [in the chlorine industry] will be concentration of growth in emerging markets and restructuring in industrialized markets: potential loss of 10–30 percent of current customers in industrialized markets; continued shutdown of inland plants linked to declining uses; three quarters of global demand growth in developing countries; increase in VCM and PVC trade and potential tripling in volume of global EDC trade. It appears unlikely at this point that lost markets will offset growth for PVC and other uses."[336]

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[329] Tullos 1995.
[330] Endo 1990.
[331] Leder et al. 1994.
[332] Mears 1995.
[333] Waltermire 1996.
[334] Endo 1990.
[335] Svalander 1996.
[336] Tittle 1995.

6. CONCLUSION

The PVC lifecycle presents one opportunity after another for the formation and environmental discharge of organochlorines and other hazardous substances. When its entire lifecycle is considered, this seemingly innocuous plastic is one of the most environmentally hazardous consumer materials produced, creating large quantities of persistent, toxic organochlorines and releasing them into the indoor and outdoor environments. PVC has contributed significantly to the world's burden of POPs and endocrine-disrupting chemicals—including dioxins and phthalates—that are now in the environment and the bodies of the human population. Beyond doubt, vinyl has caused considerable occupational disease and contamination of local environments as well.

PVC is the antithesis of a green building material. Efforts to speed adoption of safer, viable substitute building materials can have significant, tangible benefits for human health and the environment.

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EXHIBIT 6

PVC-Free Pipe Purchasers' Report

by Jamie Harvie
with Tom Lent

1) Introduction

This report provides a preliminary analysis of polyvinyl chloride (PVC) free pipe materials in construction. PVC reduction and elimination has become a priority for many government institutions, healthcare organizations, and design firms due to the serious environmental health impacts associated with the lifecycle of PVC. The pipe market represents about 50% of total PVC use in the United States. In the effort to provide leadership on pollution prevention and the protection of environmental health, the significance of modeling PVC free alternatives cannot be understated.

Based on the inventory of PVC pipe use provided, there are readily available PVC free alternatives for all pipe applications, many with a longer history on the market than PVC. Primary alternatives include ductile iron, copper, high density polyethylene (HDPE), cross liked polyethylene (PEX), concrete, and steel. Project specific design conditions may make these alternatives either less or more costly than the comparable PVC, but in general the alternative materials are cost competitive. Familiarity with a particular material is a large driver in material choice. [*]

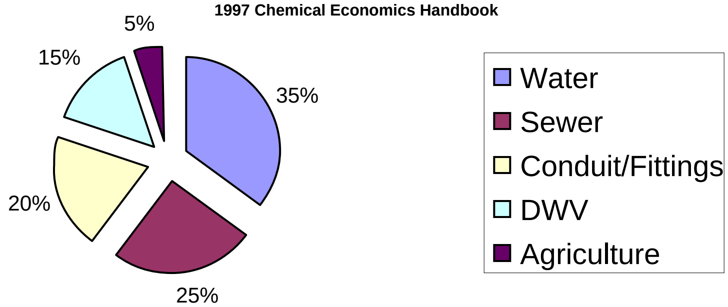
2) Summary of Pipe Sectors & Alternatives

The major pipe sectors are:

- **Water** – potable water delivery
- **Sewer** - sanitary (waste water transport outside of the building) and storm (site runoff transport)
- **Conduit /Ducting** – protection of electrical and communication wire, typically called conduit for above ground uses, and duct for below ground applications.
- **Drain/Waste/Vent** (DWV) - waste water transport within the building
- **Agriculture, Irrigation and Drainage** – water delivery for irrigation and ground drainage

Figure 1: 1996 PVC Pipe Sector Consumption (USA)

1997 Chemical Economics Handbook



[*] Note: Smaller thin walled piping, such as copper distribution, is often referred to as "tube" instead of pipe. The term "pipe" is used in this report to address both pipe and tube applications.

For each of the major piping sectors, there are a variety of alternative PVC free piping materials. This report will look at the primary alternatives (those alternative products with a large market share) in each sector using the premise that the marketplace has already determined which alternatives are most suitable and competitive to PVC.

The primary alternatives to PVC pipe in each sector are shown below in Table 1.

Table 1. Primary Alternatives to PVC by sector

Water	Ductile iron, HDPE, Concrete, Copper, PEX
Sewer	Concrete, HDPE
Conduit and Ducting	HDPE, Steel, Aluminum
Drain, Waste and Vent (DWV)	Cast Iron, Copper, ABS, PEX
Agriculture and Drainage	HDPE, Concrete

Adapted from Environment Canada report

ABS – Acrylonitrile butadiene styrene
HDPE – High Density Polyethylene
PEX – cross linked polyethylene

Acrylonitrile butadiene styrene (ABS) is not chlorinated, but like PVC has highly hazardous manufacturing intermediates, including carcinogens and is difficult to recycle. It is considered only marginally better than PVC environmentally.

High Density Polyethylene (HDPE) is available for all pipe applications. Being non-chlorinated, requiring fewer additives, and having a much higher recycling rate, it is considered a more benign plastic than PVC. PVC is more resistant to combustion, but smolders at a lower temperature than HDPE and releases toxic hydrochloric gases before combustion.

Cross linked polyethylene (PEX) is a polyethylene similar in many characteristics to HDPE but with molecules cross linked to improve its ability to handle higher temperatures.

Copper is highly recyclable but copper leaching into water supplies can be harmful to aquatic life. Copper also has significant life cycle problems in its mining and manufacture.

Concrete, iron and steel have significant embodied energy usage and their manufacture is not environmentally benign. However, all of them (with the exception of ABS) are generally considered environmentally superior to PVC. Aside from concrete, the primary PVC free alternatives are consistent with state government and professional association Environmentally Preferable Purchasing (EPP) guidelines (www.apwa.net/Documents/GovtAffairs/Policies/SolidWaste/solid-environpolicy.pdf). Steel, HDPE and copper pipe or conduit may all contain recycled content in the product. Quantities and post consumer content will vary with application and manufacturer.

3) Cost issues

A detailed cost analysis of the alternatives is beyond the scope of this report. It is important to note, however, that material costs for the pipe itself are frequently a relatively small fraction of the total project cost. While the pipe costs itself can vary considerably over time and geography due to market location and material/resin costs, there are a variety of other variable that can affect project cost. These include but are not limited to the experience and comfort level of the contractor with a particular pipe material, soil and other site conditions, installation method, and local labor costs which can have a dramatic impact on total pipe project costs. An analysis of PVC pipe alternatives by Environment Canada found that PVC alternatives are generally cost comparable. The costs of substituting for PVC pipe in the municipal pipe market represented 3% (high) and 1% (low) of total revenues from water and sewer rates. (http://www.on.ec.gc.ca/water/greatlakes/data/chlor-alkali/ A Technical and Socio-Economic Comparison of Options to Products Derived From the Chlor-alkali Industry).

Conversation with industry officials and literature review suggest that pipe material cost differences, to the extent that they do exist, are often not the determinant issue in pipe selection. In many instances in the pipe market, the choice of material has less to do with real cost differences and more to do with familiarity with one pipe type and a resistance to change. This is an important discussion in the context of value engineering. The fact that a wide range of PVC free materials have maintained significant market share in competition with PVC indicates that each of the alternatives already has broad market acceptance and demonstrated effectiveness.

4) Alternative materials comparison issues

The long-term durability of piping systems depends on many factors, including the soil environment, proper installation, material properties such as corrosion resistance, chemical resistance and strength and the performance of joints. (Env. Canada). Each of the primary PVC free materials have benefits that have kept them as significant market players.

A) Water

The water distribution piping market is typically divided into small diameter pipe (4" - 12") and large diameter pipe (14" - 36"). Smaller pipe and tubing (under 4") is used for distribution within buildings. Sewage pipe has been categorized into three size segments: small (4" - 15"), medium (18" - 36") and large sizes (over 36"). Small diameter pipe accounts for about 65% (by length) of total demand for pipe. See Table 2.

Systems are a tree-like pipe network consisting of:
Transmission lines - (water mains - typically 36" diameter or less)
Distribution lines - (lower diameter sizes: 6" - 12")
Service connections - (from street to building) 4" and less

Water mains typically operate at pressures from 100 to 150 lbs per sq. in. (psi), while distribution lines operate between 40 and 100 psi. Service connection lines are usually a diameter of 1" or less and can be made of various materials: polyethylene, PVC, iron or copper pipe. (Env. Canada)

Currently, PVC has a dominant share of the market for small diameter pipe in the water main (4" - 12"), sanitary sewer and storm sewer (4"-15") markets, while traditional materials (ductile iron and concrete) continue to have majority market share in the larger diameter pipe. (Env. Canada). According to the Plastics News (July 16, 2001) the demand for large diameter pipe plastic pipe has increased 8.3% between 1990 and 2000.

The smaller tube sizes used for in building distribution are primarily split between PVC, copper, and iron. There is limited data on the breakdown of market share.

Polyethylene is just beginning to penetrate the market for all sizes.

The use of galvanized steel and polybutylene has declined due to corrosion problems with galvanized and catastrophic failures with polybutylene.

One of the key design concerns for drinking water infrastructure design and installation is leakage. When one turns on the tap for potable water, there is a cost associated with the acquisition, treatment, and supply (pumping) of the waster. If a water distribution system leaks, the lost water can become an extremely high cost. In arid areas, such as the American Southwest, where costs to acquire water can be exorbitant, leaks can be an expensive proposition. In Charleston West Virginia, a 4 inch leak in their 24 inch diameter iron pipe resulted in the loss of 3 to 5 million gallons of water per day. In Washington D.C, there is about 66 million gallons of water unaccounted for. (Plastics Pipe Institute Fall 2002)

HDPE has a slight advantage in leak resistance over PVC. This is because it can be delivered in longer lengths, minimizing the quantity of joints. Furthermore, the butt or electro-fusion processes used to join HDPE provides stronger, tighter, more leak proof joints compared to the bell and spigot joints used in PVC pipe for mains or the solvent glue joints used for smaller distribution. The longer length of HDPE can require longer trenches to be open at a time, but its length and flexibility can allow for trenchless procedures, particularly in sewer replacement. HDPE's greater flexibility and resilience (particularly at lower temperatures) also make it less susceptible to surge and hammer shocks or to damage from digging. HDPE's flexibility and resilience has made it increasingly popular in earthquake territory or other areas where soils can shift. For larger diameters, the fusion technique requires a fusion machine, which might be problematic in cramped spaces. For smaller diameter pipes, a handheld device can be used to weld/melt the pipe lengths together. Mechanical couplings are available for HDPE, though some of these couplings may be made of PVC.

PEX is another form of polyethylene that retains HDPE's flexibility and chemical resistance while providing resistance to higher temperatures for which HDPE is not suitable. It is coupled with either fusion techniques or mechanical crimp couplings. Due to its higher temperature ratings it was initially used in radiant and district heating system applications, but is now also beginning to be used more widely in water supply and gas distribution systems.

Ductile Iron (DI) has significantly higher tensile strength, making it more capable of handling higher pressures, crushes and hammer than PVC. DI does not lose strength at high or low temperatures as PVC does. Ductile iron is impermeable to hydrocarbons and other groundwater contamination unlike PVC or other plastic pipe.

"There has been much debate over the durability and expected lifespan of each of these materials. The life of a pipe system depends not only on the material, but the installation and the surrounding environment. All these types of pipe have been on the market for over 30 years, and while there are examples of pipe failures for each of them, this study did not find conclusive evidence to suggest that one material has a significantly different lifespan from the other. When properly designed and installed, pipe systems of any of these materials can be sufficiently durable to withstand many decades of services." (Env. Canada)

B) Sewer

Prior to the 1960s most sewer systems were combined sewers, that is, carried both sanitary and storm water. The system had to be designed to carry large volumes of water during rain events, but otherwise the capacity was little used. In addition, when it did rain the flood of relatively fresh water often negatively impacted water treatment. Design changed so that by the mid 1960s sanitary and storm systems were designed and constructed separately. Storm sewers collect water from roof drains, parking lots and streets. Unlike sanitary sewers, storm wastewater is not typically treated and the flow is directly discharged into a receiving body of water.

Similar to water distribution use, PVC is dominant in the smaller size sewer pipe market with HDPE just beginning to seriously compete. These smaller lines are commonly used in the collection network of subdivisions. In this segment, the competing concrete pipe is non-reinforced concrete pipe in 8" and 10" sections. The smallest diameter reinforced concrete pipe is usually 12" pipe.

As in water main pipe, HDPE is a comparable alternative to PVC pipe in sewer systems. HDPE sewer pipes are also available in diameters ranging from 4 inches to 36 inches, although for storm sewer, much of the demand is for 10 to 15 inch, while for sanitary 8 to 12 inch are popular diameters. At larger diameters, the major market share is held by concrete, primarily due to cost.

C) Conduit and Ducting

Galvanized steel and aluminum are the traditional conduit materials. Over the last few decades PVC has been able to take a large share of this market. Over the last decade HDPE has seen the most growth in the conduit sector, and easily competes with PVC. There is limited data on the breakdown of market share. HDPE's extremely low coefficient of friction makes it easy to pull cable through; one reason for its increasing popularity. Fire code concerns have limited HDPE acceptance for indoor conduit applications making it the primary alternative to PVC for outdoor and underground applications. Steel and aluminum conduit are the primary alternatives to PVC for indoor applications. While PVC is fire resistant, it's tendency to smolder and emit hydrochloric gases before combustion is a particularly dangerous attribute in medium and high voltage conduit applications. HDPE comes in rolls of several hundred feet while PVC and metal conduits comes in rigid 20 foot sections. This makes HDPE easier to use for larger installations and metal easier for smaller installation. Some metal conduit products may be coated with PVC. It is important to specify those products that are PVC free.

D) Drain Waste and Vent (DWV)

Cast Iron and copper are the traditional DWV materials. PVC is widely used in residential construction because of the ease of joining with solvent glues. ABS and PEX have both become popular alternatives to PVC in more recent years. As previously noted, ABS has serious environmental problems of its own.

E) Agriculture, Irrigation & Drainage

A variety of alternatives to PVC are used both for water delivery and for drainage. Irrigation sprinkler, drip and drainage systems have long been available in HDPE and have significant advantages in resilience against compression, shovel attack and ground movement. Corrugated steel, concrete and HDPE are all competitive alternatives for drainage. HDPE drainage pipe is now available in formulations with high recycled content. Plastic pipe has carved a hunk of the huge market previously dominated by concrete and steel. Highway drainage is a fast growing market for HDPE. Recently, the Corrugated Polyethylene Pipe Association initiated a third party certification system which allows for increased acceptance of their product by the American Association of State Highway and Transportation Officials. Footing and underslab drains are all available in HDPE.

5) Obstacles to Change

Journal articles and reports have some consensus as to why PVC has made such strong inroads in the water and sewer markets, and why HDPE, a viable alternative resin, has had difficulty in the market place. Primarily it has to do with what was there first, and a resistance to change.

According to an Environment Canada report, “In the case of HDPE, one reason for the low market share is the different marketing strategies initially employed for PVC and HDPE. Though HDPE has always been a competing plastic, with a longer history of use in pipe than PVC, the initial target markets for HDPE pipe suppliers were industrial settings, such as the chemical process industries, and the mining sector. In contrast, PVC pipe suppliers, who also sold ductile iron pipe, targeted municipal infrastructure pipe markets. As a result, municipal design engineers and contractors are more familiar working with PVC pipe, and seldom specify or design HDPE systems.” (Env. Canada)

A trade journal article reporting on the difficulty in breaking into the market reports, “Even though polyethylene pipe has gained AWWA acceptance, U.S. water utilities and the engineers who design water systems have been slow to consider it as an alternative to the products they know and have used for years. Why risk trying something that – to the potable water industry- is new? (Underground Construction, June 2000).

One of the great barriers to changing the PVC water and sewer market is the resistance to change. Most engineers, contractors and public works officials have been working with the same materials for a long time, have become very familiar with their characteristics and are not anxious to take on a new material with different characteristics.

Appendix A – PVC Consumption Breakdowns

PVC Pipe Market

The figure below categorizes PVC consumption and demonstrates that construction consumes over three quarters of the PVC in the US and hence is the most significant end use of PVC (Figure 1).

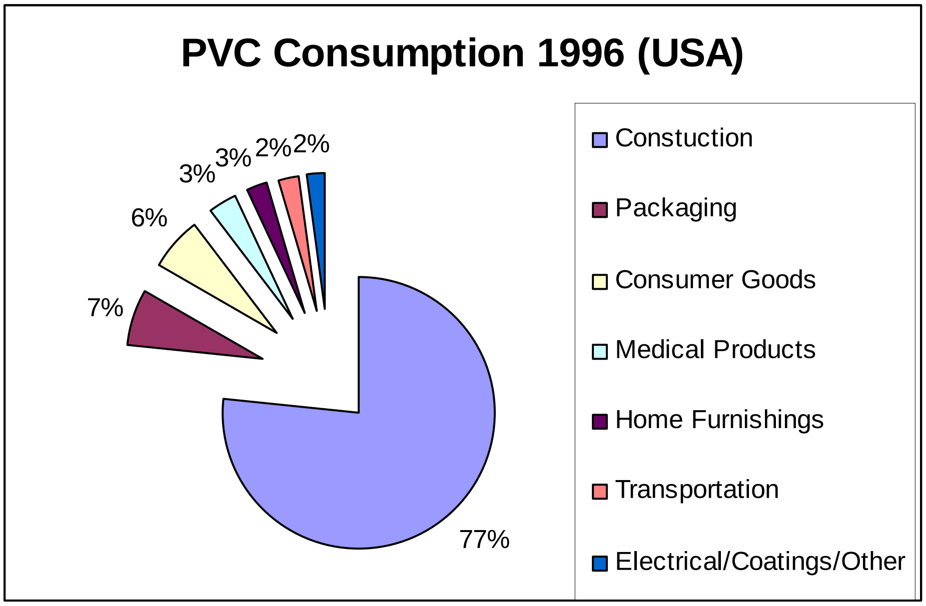


Figure 1.

Figure 2 depicts a sub-sector breakdown of PVC use in the construction sector and shows that the most significant segment is Pipes, tubing and fittings consuming about 2/3 of the total (Figure 2).

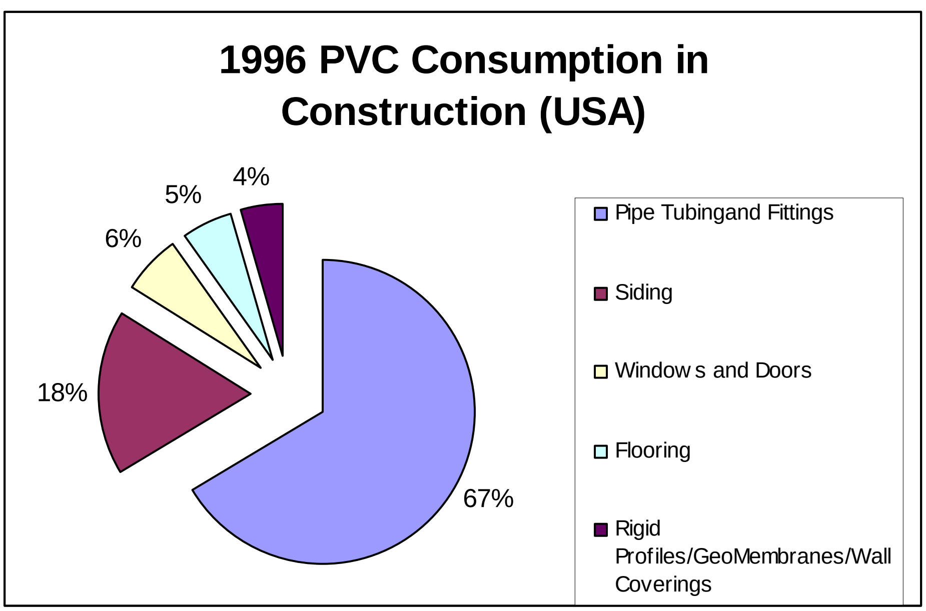


Figure 2.

Breaking out Pipes, tubes and fittings from other construction uses we see that this sub sector represents almost half of the entire PVC consumption (figure 3)

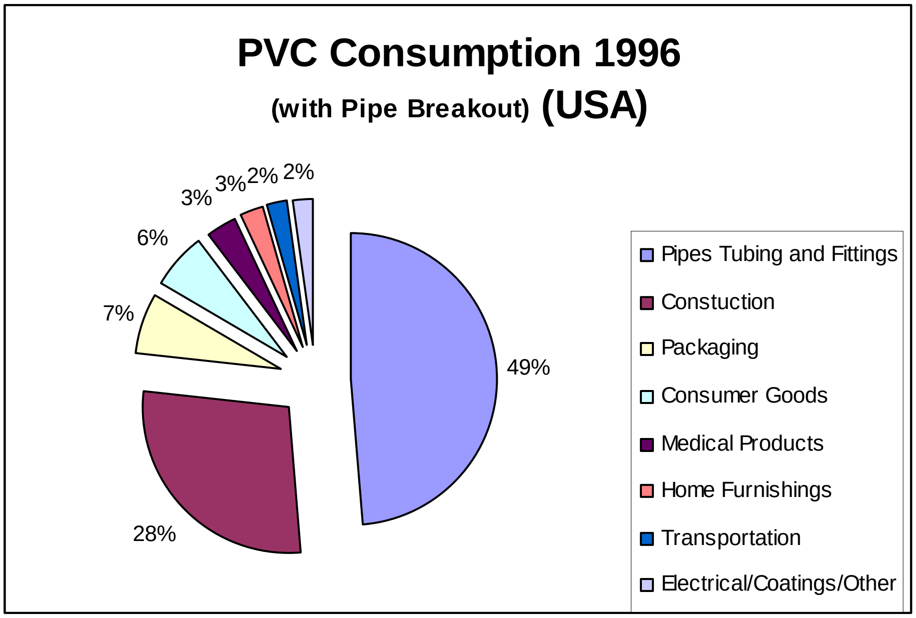


Figure 3.

The data suggests that even a small movement away from PVC pipes can significantly impact the size of the PVC market. Currently, for every 10% shift in the PVC pipe tubing fitting market, there is a corresponding 5% shift in the entire PVC market. Importantly, this does not necessarily mean other PVC sector targets should be abandoned. For example, market movement away from PVC medical devices, though smaller PVC use sector (3% of entire PVC consumption), may actually be a significant driver of the PVC pipe market, or other market sectors.

Appendix B - Sewer and Water Pipe Design Primer

The following primer is intended to provide the layperson with an introduction to pipe design, construction techniques, and associated vocabulary.

1) Engineering and Design

Water and Sewer Layout

Though it may not be obvious, pipelines are designed to follow the natural topographic variation and mimic natural drainage flow to take advantage of gravity. It is important that pipelines not be too deep to make excavation and installation prohibitively expensive, but also that the pipeline not be so shallow that it is difficult to service the building.

Pressure Pipe

In pipes, fluids are transported under two conditions; pressure or gravity flow. These two methods are important as they have implications on pipe material selection and layout. In pressure pipe, fluids are moved through the pipe by a pump, and as a result are put under pressure. Water pipes are usually pressure systems, as lakes, rivers, reservoirs, and other bodies from where water is obtained are typically located at elevations below where the water needs to be delivered. Because water does not flow against gravity, water delivery to apartment buildings, and upper floors of houses needs to be pumped, and hence is under pressure. Because the fluid is under pressure, joints for pressure systems must be rather "strong" or tight, otherwise as the pressure wave hits the joint, the pipe will fall apart, or create unacceptable leaks. Most codes for pressure pipe have what is called an allowable leakage rate. This means that the code allows for pipes to have a small degree of leakage. Pipes which are seamless, such as HDPE will have no leakage, even though it may be allowed by code. Though wastewater is typically designed for gravity flow, there are occasions where wastewater is also pumped. Usually this occurs where the topography is very flat, or where there is a hill along the pipe route.

Gravity Pipe

As implied, gravity flow uses gravity to transport the liquid. Wastewater is typically conveyed in a gravity system. A major concern with gravity systems is what is called Inflow and Infiltration (I & I) where water enters cracks or leaky joints. This is a concern for a variety of reasons. First, it can cause added expense to the wastewater plant because the plant is "forced" to treat excess water that does not require treatment. Associated with this excess dilute loading is poor wastewater treatment and unneeded treatment expense. Secondly, it can cause overflows at the wastewater plant or in the downstream conveyance system during rainstorms when pipe capacity is exceeded. This is one reason why during heavy rains wastewater plants may not function and that there are overflows. It is not necessarily because of poor system design but because breakdown of old pipe or poor construction have allowed for I&I. When a pipe collection system passes through an area of high water table, outside I&I can be problematic. The water table puts pressure on the gravity pipe, and it is continuously forced into the collection system. A US standard for sewage water infiltration allowance is 200 gallons per inch diameter per mile per day.

Corrosion
In metal water pipes, corrosion can occur because chemical reactions cause the pipe to act mildly electrically charged. This charge can cause it to release ions, causing it to lose strength. This can be remedied typically by supplying coatings such as tar or enamel.

In sewer pipes corrosion can occur because of chemical reactions caused by the biological production of sulfuric acid. In concrete pipes, the acid reacts with the lime to form calcium sulfate which lacks structural strength. The best protection is corrosion resistant pipe such as vitrified clay or plastic. Concrete pipe can be protected with coatings and or linings.

Flexible Pipe
Pipes with higher flexibility, such as PVC and HDPE (and larger diameter ductile iron) require proper pipe bedding and full sidefill support to resist deflection. The bedding, the sidefill and the walls of these "flexible" pipes must form a structural unit to resist the pipe deflection caused by overlying soil loads. In practice, this means that these pipes require increased labour and materials for backfilling and sidefilling.

Joints

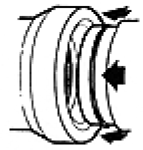
There are a variety of ways in which pipes are joined. These are:

- **Mechanical –** a joint where pipes are joined by bolting or threaded their ends together.

- **Solvent Cement –**Solvents are used to join PVC DWV pipe. The solvent is used to soften and "glue" two pipe sections together. Health concerns have been raised about these solvents.

- **Welded –** both metal and some plastic pipes can be welded. Plastic pipe uses a hot plate to melt the ends of the plates to be joined. The plate is removed and the ends are pushed together using joining machinery, creating a seamless joint.

- **Bell and Spigot –** Bell and spigot joints are often used in gravity lines. With bell and spigot joints, each pipe length has a bell (or larger diameter end piece) end and spigot (or normal diameter) end. The spigot is inserted into the bell via a compression fit. Much sewer work uses bell and spigot joints.



Bell and Spigot Joint
best fit gasket company http://www.bestfitt.com/instructions/prepjoin.htm

2) Construction

Traffic
Traffic can add significant changes to pipeline project. In a new subdivision, the entire pipeline length can be excavated and the pipe placed without disturbing circulation. In an urbanized area, because of traffic flow and associated safety concerns, it can be almost impossible to dig up an entire street to lay pipe. When pipe is place in urbanized areas, the street is typically dug up section by section. A section of pipe is laid,

the hole backfilled, the adjacent section of street excavated, the new piece of pipe joined, and the hole backfilled. In this way, the excavation site "moves" along the route of the new pipeline with little disruption of street level traffic. This type of construction requires the joining of pipe sections to form one contiguous pipeline versus the placement of one long section of pipe. One disadvantage to this form of pipeline placement are that there are many joints each with the potential for failure or leakage The advantage is that there is little disruption to above grade activities. Trenchless technologies which favor HDPE pipe are now becoming commonplace.

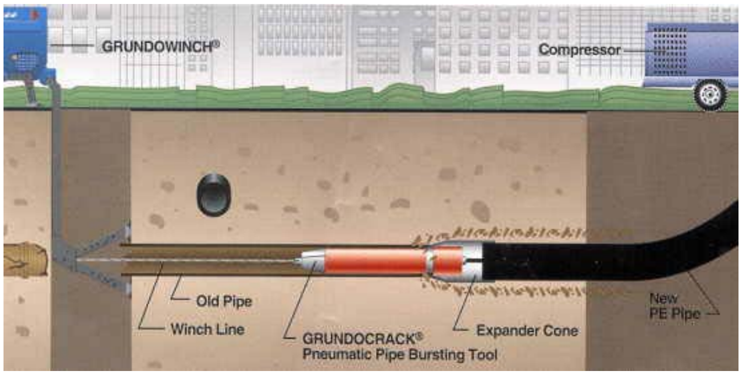
Trenchless Technologies

i) Sliplining

If an older pipe is to be replaced, sliplining is frequently used to minimize installation costs. Costs are minimized because no excavation is required. Sliplining involves the placement of newer pipe inside that of an older, usually failed pipe. As the inside diameter of the "new' pipe will be smaller than the old, the new smaller pipe diameter will be able to carry less flow so this method requires that there be excess capacity in the older larger pipe. The new pipe, in lengths of 1000m can either be pushed of pulled through the older pipe. (PM Construction)

ii) Pipe Bursting

This is a relatively new technique for pipe placement. It is the only trenchless technology that allows for the replacement pipe to have larger diameter than the original pipe. In this method, a pneumatic bursting machine is dragged through the existing pipe. Old pipe fragments are displaced into the surrounding soil and the new larger pipe, in lengths up to 500 meters, is pulled in behind as replacement.



Appendix C - Case Studies

The following case studies have been provided to show examples of where and how PVC alternatives are used. All these case studies illustrate the use of HDPE, not because it is the preferred alternative to PVC, but because the other alternatives (ductile iron, copper, concrete) have already proven themselves in the North American marketplace.

Western Lake Superior Sanitary District commits to PVC free pipe The Western Lake Superior Sanitary District (WSLLD) is a regional wastewater treatment plant located in Duluth, Minnesota. It is the largest American point source discharge to Lake Superior. The WLSSD, has adopted a nationally recognized pollution prevention program which has as its basis a commitment to zero discharge of persistent toxic substances. This commitment reads:

> "The WLSSD as a discharger to Lake Superior is committed to the goal of zero discharge of persistent toxic substances and will establish programs to make continuous progress toward that goal. The District recognizes step-wise progress is only possible when pollution prevention strategies are adopted and rigorously pursued. These approaches will focus upon our discharge as well as indirect sources. WLSSD will work with its users to implement programs, practices, and policies which will support the goal.... WLSSD recognizes that airborne and other indirect sources beyond District control must be addressed in order for significant reductions to occur."

One component of their P2 program is a PVC free policy as a means towards dioxin reduction. As a wastewater treatment plant this policy has been applied to assist in the purchase of PVC-free pipe, an alternative PVC-free liner for their new anaerobic digestion facility, preference for PVC alternatives in their master plan development, PVC free electrical applications, and in the elimination of other uses of PVC such as office products. www.wlssd.duluth.mn.us

Bow, NH uses HDPE for roadway drainage. The community of 6,500 residents has 110 miles of roadway, and as old roads are upgraded and new roads built, the town includes storm drains made of HDPE. The corrugated polyethylene pipe was chosen for its ability to withstand frost action in the varied soil conditions beneath the town. "Metal pipe and cement pull apart from heat, and the freeze-and-contract movement in the winter. If there's a pocket of clay, water beneath the surface humps it up when it freezes, and that makes metal pipe come apart at the joints," comments Cleverly, the city engineer, noting that he hasn't seen any similar problems with corrugated polyethylene pipe. Additionally, Cleverly likes the safety factor HDPE pipe provides over metal pipe. He describes freshly-cut metal pipe ends as, "razor-sharp," compared to HDPE. "We try to be as safety-conscious as possible," he says. (CPPA website)

Atlanta Parks & Recreation uses 4" and 6" perforated polyethylene pipe to improve the hydraulic performance of a series of French drains running through the park and alongside a ball field. The Artis Group, Decatur, Ga., installed 1,000 linear feet of perforated pipe down the center of the drains to speed water flow. The smooth interior of the pipe provided greater hydraulic efficiency than ditches alone. (CPPA website)

HDPE pipe chosen for municipal sewer lines in Missoula, MT. City engineers evaluated all types of pipe and chose Hancor corrugated polyethylene. (Hancor Inc. website)

Appendix D – PVC Alternative comparisons

Technical Comparison of PVC and Ductile Iron Pipe

Technical Characteristics	PVC	Ductile Iron
Material Properties		
Corrosion Resistance	Resistant to acids	Can corrode; requires protection in some acidic soils and septic waters
Chemical Resistance	Can soften/degrade with organic solvents at high concentrations	Resistant to organic solvents; requires protection from acids
Impact Resistance	Moderate	High
Hydrostatic strength	Moderate	High
Tensile Strength	Moderate	High
Pipe Stiffness	Flexible; bends moderately	Flexible; bends slightly
Installation Factors		
Handling, weight	Light (~15 kg/m - 8" DR 18)	Heavy (32-36 kg/m - 8" Class 350)
Joining	Push on joints most common; mechanical and butt-fusion joints possible	Push-on joints most common; accommodates some deflection; mechanical joints possible
Bedding	generally requires more sidefill support to control deflection	more rigid at lower diameters; still requires careful bedding
Service		
Durability	High	High (with corrosion control as required)
Joint Integrity	Long term reliability	Long term reliability
Water Flow	Smooth walls; low friction factor	Slightly higher friction factor; larger internal diameter; higher flow
Temperature Range	Lower impact resistance with decreasing temperatures; lower tensile strength with increasing temperatures	Handles very high and low temperatures

Source: Env. Canada

Technical Comparison of PVC and HDPE Pipe

Characteristic	**PVC**	**HDPE**
Durability	Decades	Decades
Joining	bell and spigot push-on	butt-fusion above ground mostly, bolted flange for equipment connections
Joint integrity	tight seals; low leakage	butt-fusion results in tight seals
Weight	more dense than HDPE	less dense than PVC
Ductility	more stiff than HDPE	less stiff then PVC
Flexibility	rigid	flexible
Pressure rating	more susceptible to surge, hammer shocks	less susceptible to surge, hammer shocks
Tensile strength	PVC has better strength to volume ratio	HDPE has less strength to volume ratio
Internal wall smoothness	close to HDPE	close to PVC
Abrasion resistance	moderate	high
Chemical resistance	moderate	very good
Impact resistance	brittle at very low temperature, glass transition temperature higher than HDPE	better low temperature resistance, glass transition temperature lower than PVC
Fire resistance	will not sustain combustion	will sustain combustion
Tapping	mechanical taps	fusion or mechanical tapping

Env. Canada

Technical Comparison of PVC and Concrete Sewer Pipe

Technical Characteristics	**PVC**	**Concrete**
Material Properties		
Corrosion Resistance	Resistant	resistant
Chemical Resistance	susceptible to some hydrocarbon solvents	susceptible to acids (i.e. sulphuric acid); solvents may cause dissolution
Impact Resistance	moderate; reduced at very low temperatures	moderate
Abrasion Resistance	High	high; moderate under acidic conditions
Tensile Strength	moderate; flexible	high; rigid sections; flexibility in system due to shorter lengths
Soil Stress Resistance	flexible; withstands stress with sidefill support	withstands high soil loads
Installation Factors		
Handling, weight	light (13 kg/m); long (6.1m) sections (8" basis)	heavy (72 kg/m); short (1.2 m) sections (8" basis)
Joining	push on joint	push-on joint; more joints
Bedding	180° bed tamping required	lower half support may be necessary
Service		
Durability	high; long life span expected, not proven beyond 30 years	high; long lifespan
Joint Integrity	long-term reliability with proper installation	long-term reliability with proper installation
Water Flow	smooth walls; low friction	smooth walls; low friction
Temperature Range	lower impact resistance with decreasing temperatures; flexibility increases with increasing temperatures	wide range application

Env. Canada

Technical Comparison of PVC and HDPE Sewer Pipe

Characteristic	PVC	HDPE
Durability	decades	decades
Joining	bell and spigot push-on	bell and spigot push-on, butt-fusion, clam shell connections
Joint integrity	tight seals; low infiltration	tight seals; low infiltration (higher for clam shell enclosures)
Weight	more dense than HDPE	less dense than PVC
Ductility	less ductile than HDPE	more ductile than PVC
Flexibility	flexible	flexible
Tensile strength	better strength/volume ratio	lower strength to volume ratio
Internal wall smoothness	close to HDPE	close to PVC
Abrasion resistance	moderate	high
Chemical resistance	softens with solvents at high concentrations	very good
Impact resistance	decreases at very low temps., glass transition temp. higher than HDPE	better low temp. resistance, glass transition temp. lower than PVC
Fire resistance	resistant to combustion	will sustain combustion

Env. Canada

Water and Sewer Pipe Market Share, 1993
(% of length) (what about <4"?)

Type of Pipe	Water main		Sanitary and Sewer Pipe		
	4"-12" (Small)	14"-36" (Large)	4"-15" (Small)	18"-36" (Medium)	36"+ (Large)
PVC	88%	25%	85%	34%	0%
HDPE	0%	10%	5%	2%	0%
Ductile iron	12%	35%	0%	0%	15%
Concrete	0%	30%	10%	64%	85%
Total	100%	100%	100%	100%	100%

Table 2. Environment Canada

APPENDIX E: Manufacturers and suppliers of HDPE piping

Agents Private International (HDPE duct and conduit)
Richmond Hill, Ontario, Canada
416-281-6902
http://www.agtprint.com

Arnco (HDPE conduit and duct)
Elyria, OH
800-321-7914
www.arncocorp.com

Chevron Phillips Chemical Company LP (HDPE pipe & conduit)
The Woodlands, TX
(800) 231-1212
http://www.cpchem.com

Endot Industries, Inc. (HDPE pipe and conduit)
Rockaway, NJ
1-800-44-ENDOT(443-6368)
http://www.endot.com/market/

Hancor (recycled HDPE drainage drain)
Findley, OH
1-888-FOR PIPE
www.hancor.com

ISCO Industries, LLC (HDPE pipe)
Louisville, KY
1-800-345-ISCO
www.isco-pipe.com

Lamson & Sessions (HDPE conduit)
Cleveland, Ohio
Phone: (800) 321-1970
http://www.lamson-sessions.com/news_hdpeconduit.htm

Vanguard Piping Systems (HDPE and PEX piping)
McPherson, Kansas
1-800-775-5039
www.vanguardpipe.com

Wis. Plastic Drain Tile (HDPE drain tile and piping, 100% recycled)
Jefferson, WI
800-362-6642
http://www.draintile.com/

Blackburn Nursery's Home & Garden Showplace (HDPE irrigation)
4100 SW 40th St.
Topeka, KS, 66611
(785)-272-2707
http://www.blackburnnursery.com/sprinklers/irrigation_pipe.shtml

Local Sources (California Bay Area)

AllBay Plumbing Supply Inc
2815 E 10th St, Oakland, Ca 94601
Phone:510-533-5060 Fax: 510-533-3590
Vanguard Products

Maskel-Robbins
3135 Diablo Avenue
Hayward, CA 94545
800-638-4373
Don Wescott, rep 510-612-5844 (cell)

P&F Distributing
511 Tunnel Ave.
Brisbane, CA 94005
415.467.4630
Ask for Navy Nesbit.

Cagwin & Dorward (HDPE irrigation installation)
Novato, CA
707-545-3134
Bob Giordano

Wyatt and Ewing Supply carry irrigation HDPE pipe.
They may also have the larger sizes to use for main lines and high pressure supply lines

Healthy Building Network
2425 18th Street NW
Washington DC 20009
www.healthybuilding.net

EXHIBIT 7

Preventing Work-Related Coccidioidomycosis (Valley Fever)

Valley Fever is an illness that usually affects the lungs. It is caused by the fungus *Coccidioides immitis* that lives in soil in many parts of California. When soil containing the fungus is disturbed by digging, vehicles, or by the wind, the fungal spores get into the air. When people breathe the spores into their lungs, they may get Valley Fever.

Is Valley Fever a serious concern in California? YES!

Often people can be infected and not have any symptoms. In some cases, however, a serious illness can develop which can cause a previously healthy individual to miss work, have long-lasting and disabling health problems, or even result in death.

This fact sheet describes actions employers can take to prevent workers from getting Valley Fever and to respond appropriately if an employee does become ill.

> **➤ In October 2007, a construction crew excavated a trench for a new water pipe. Within three weeks, 10 of 12 crew members developed coccidioidomycosis (Valley Fever), an illness with pneumonia and flu-like symptoms. Seven of the 10 had abnormal chest x-rays, four had rashes, and one had an infection that had spread beyond his lungs and affected his skin. Over the next few months, the 10 ill crew members missed at least 1660 hours of work and two workers were on disability for at least five months.**

FACT SHEET HESIS

HAZARD EVALUATION SYSTEM & INFORMATION SERVICE
California Department of Public Health, Occupational Health Branch
850 Marina Bay Parkway, Building P, 3rd Floor, Richmond, CA 94804
510-620-5757 • www.cdph.ca.gov/programs/ohb

JUNE 2013

California Department of Public Health • California Department of Industrial Relations

How do workers get Valley Fever?

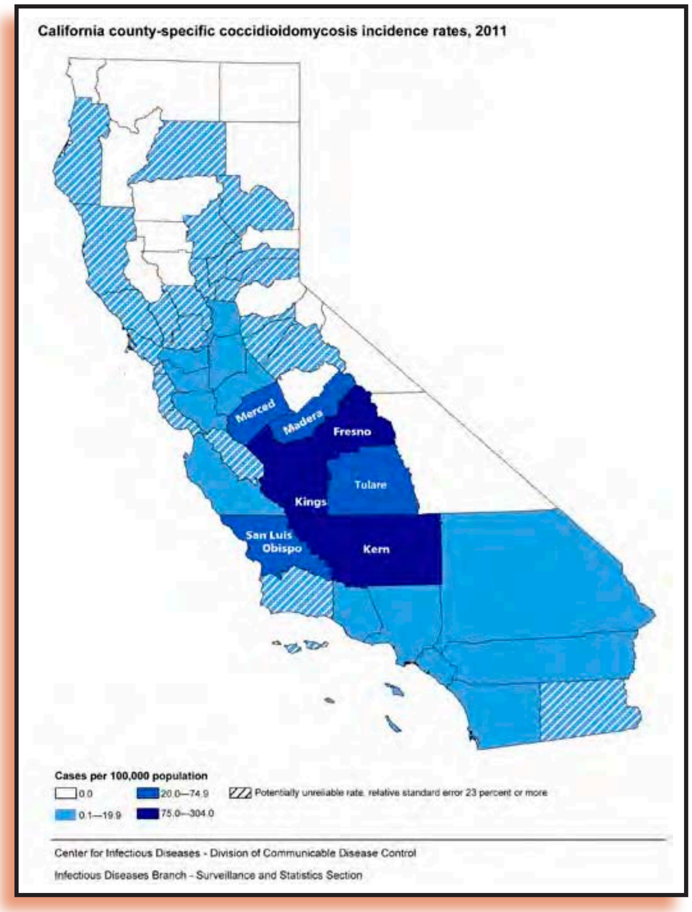
In California, Valley Fever is caused by the fungus *Coccidioides immitis* that lives in the top two to 12 inches of soil in many parts of the state. When soil containing this fungus is disturbed by activities such as digging, vehicles, or by the wind, the fungal spores get into the air. When people breathe the spores into their lungs, they may get Valley Fever. Fungal spores are small particles that can grow and reproduce in the body. The illness is not spread from one person to another.

How do employers know if the fungus is present in soil at their worksites?

The Valley Fever fungal spores are too small to be seen by the naked eye, and there is no reliable way to test the soil for spores before working in a particular place. Some California counties consistently have the Valley Fever fungus present in the soil. In these regions Valley Fever is considered endemic. Health departments track the number of cases of Valley Fever illness that occur. This information is used to map illness rates as seen on the figure above. Employers can contact their local health department for more information about the risk in their counties.

Where do people get Valley Fever?

Highly endemic counties, i.e., those with the highest rates of Valley Fever (more than 20 cases per 100,000 population per year), are Fresno, Kern, Kings, Madera, Merced, San Luis Obispo, and Tulare. Other counties or parts of counties also have the fungus present.



California county-specific coccidioidomycosis incidence rates, 2011

Who is at risk for Valley Fever?

Workers who disturb the soil by digging, operating earth-moving equipment, driving vehicles, or working in dusty, wind-blown areas are more likely to breathe in spores and become infected. Some occupations at higher risk for Valley Fever include:

- Construction workers, including road-building and excavation crews
- Archeologists
- Geologists
- Wildland firefighters
- Military personnel
- Workers in mining, quarrying, gas and oil extraction jobs
- Agricultural workers*

* Cultivated, irrigated soil may be less likely to contain the fungus compared to undisturbed soils.

Anyone, even healthy young people, can get Valley Fever. Once a person has had Valley Fever, their body may develop some immunity against future infections.

How does Valley Fever affect health?

- Experiments on laboratory animals indicate that a very small dose, 10 spores or fewer, may cause an infection.
- After breathing in the spores, the following can happen:
  - In about 60% of cases, symptoms are mild or not present.
  - In about 40% of cases, symptoms vary from moderate to severe. Usually symptoms are those of a flu-like illness that may last up to a month but goes away on its own. However, some people develop pneumonia (at times severe).
  - In a small proportion of cases (about 5%), disease spreads outside of the lungs causing very serious illness. Parts of the body that may be affected include the brain (meningitis), bones, joints, skin, or other organs. This is called ***disseminated Valley Fever*** (or disseminated coccidioidomycosis).
- People who are more likely to have severe or disseminated Valley Fever include those who have weakened immune systems, such as people who are HIV positive, have AIDS, cancer, or diabetes; who smoke; or who are pregnant. People of African and Filipino descent are much more likely to get disseminated disease; however, others can get disseminated disease, too.

Earth-moving equipment may stir up spores

What are signs or symptoms of Valley Fever?

When present, symptoms usually occur between seven to 21 days after breathing in spores, and can include:

- Cough
- Fever
- Chest pain
- Headache
- Muscle aches
- Rash on upper trunk or extremities
- Joint pain in the knees or ankles
- Fatigue.

Symptoms of Valley Fever can be mistaken for other diseases such as the flu (influenza) and TB (tuberculosis), so it is important for workers to obtain medical care for an accurate diagnosis and possible treatment.

Disseminated Valley Fever

Dissemination refers to spread of infection beyond the lungs to other parts of the body. With Valley Fever this usually occurs within the first six to 12 months after the initial illness.

Signs or symptoms of disseminated Valley Fever may vary but usually consist of some combination of the following:

- Fever
- Raised skin lesions with irregular surfaces
- Lymph node swelling, especially in the neck
- Pain and swelling in one or more joints
- Recurrent, persistent, new headaches (may be mild)
- Stiff neck.

Preventing Valley Fever exposure

There is no vaccine to prevent Valley Fever. Employers can reduce worker exposure by incorporating the following elements into the company's Injury and Illness Prevention Program and project-specific health and safety plans:

1. Determine if the worksite is in an area where Valley Fever is endemic (consistently present). Check with your local health department to determine whether cases have been known to occur in the proximity of your work area. See the map on page 2 to determine whether your company will be working in an endemic county.

2. Train workers and supervisors on the location of Valley Fever endemic areas, how to recognize symptoms of illness (see page 3), and ways to minimize exposure. Encourage workers to report respiratory symptoms that last more than a week to a crew leader, foreman, or supervisor.

3. Limit workers' exposure to outdoor dust in disease-endemic areas. For example, suspend work during heavy wind or dust storms and minimize amount of soil disturbed.

4. When soil will be disturbed by heavy equipment or vehicles, wet the soil before disturbing it and continuously wet it while digging to keep dust levels down.

5. Heavy equipment, trucks, and other vehicles generate heavy dust. Provide vehicles with enclosed, air-conditioned cabs and make sure workers keep the windows closed. Heavy equipment cabs should be equipped with high efficiency particulate air (HEPA) filters. Two-way radios can be used for communication so that the windows can remain closed but allow communication with other workers.

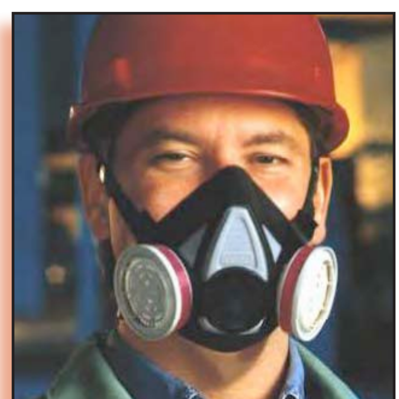
6. Consult the local Air Pollution Control District regarding effective measures to control dust during construction. Measures may include seeding and using soil binders or paving and laying building pads as soon as possible after grading.

7. When digging a trench or fire line or performing other soil-disturbing tasks, position workers upwind when possible.

8. Place overnight camps, especially sleeping quarters and dining halls, away from sources of dust such as roadways.

PAPR with helmet (APF=1000)

Full-face respirator (APF=50)



Half-mask respirator (APF=10)

9. When exposure to dust is unavoidable, provide NIOSH-approved ***respiratory protection*** with particulate filters rated as N95, N99, N100, P100, or HEPA. Household materials such as washcloths, bandanas, and handkerchiefs do not protect workers from breathing in dust and spores.

Respirators for employees must be used within a Cal/OSHA compliant respiratory protection program that covers all respirator wearers and includes medical clearance to wear a respirator, fit testing, training, and procedures for cleaning and maintaining respirators.

Different classes of respirators provide different levels of protection according to their Assigned Protection Factor (APF) (see table below). Powered air-purifying respirators (PAPRs) have a battery-powered blower that pulls air in through filters to clean it before delivering it to the wearer's breathing zone. PAPRs will provide a high level of worker protection, with an APF of 25 or 1000 depending on the model. When PAPRs are not available, provide a well-fitted NIOSH-approved full-face or half-mask respirator with particulate filters.

Fit-tested half-mask or filtering facepiece respirators are expected to reduce exposure by 90% (still allowing about 10% faceseal leakage), which can result in an unacceptable risk of infection when digging where Valley Fever spores are present.

The table below shows the relative effectiveness of various types of respirators for particles of dust and spores.

Respiratory Protection for Reducing Dust and Spore Exposure

	Respirator Type (worn with particulate filters)	**Assigned Protection Factor (APF)**	**Expected Reduction of Exposure to Dust and Spores (%)**
	No respirator	None	0
Increasing Protection ↓	Half-mask respirator (elastomeric or filtering facepiece)	10	90
	Powered air-purifying respirator with loose-fitting face covering	25	96
	Full-face respirator	50	98
	Some powered air-purifying respirators are designed to offer higher protection (check with manufacturer)	1000	99.9

Preventing transport of spores

- **Clean tools, equipment, and vehicles with water to remove soil before transporting offsite** so that any spores present won't be re-suspended in air and inhaled at a later time.
- **Provide workers with coveralls or disposable Tyvek™ daily.** At the end of the work day, require workers to remove their work clothes at the worksite.
- **Keep street clothes and work clothes separate by providing separate lockers or other storage areas.** If possible, store work boots at the worksite; otherwise, have workers use a boot wash before getting into their vehicles.
- **Encourage workers to shower and wash their hair at the workplace** (if at a fixed location) or as soon as they get home.

What should employers do if a worker reports Valley Fever symptoms?

- If the worker disturbed soil or otherwise did dusty work in an endemic area, **the employer should send the worker to their workers' compensation health care provider or occupational medicine clinic**. The employer should provide the health care provider with the details about the dust or soil exposure. The worker should give a copy of this fact sheet to the health care provider.
- When two or more workers report symptoms that suggest Valley Fever, workers should be sent to a single medical provider or occupational medicine clinic for coordinated medical care, if possible. This can facilitate better communication between the medical provider, public health agencies, and employer.
- **Travel through endemic areas has resulted in Valley Fever cases.** When a worker who has traveled through an endemic area reports a respiratory illness that lasts more than a week, the employer should send the worker to their workers' compensation health care provider or occupational medicine clinic.
- **Complete the "Employer's Report of Occupational Injury or Illness" (Form 5020) for each occupational Valley Fever illness** which results in "lost time" or medical treatment beyond first aid.
- **List cases on the Cal/OSHA Form 300,** "Log of Work-Related Injuries and Illnesses".
- **Report immediately any serious injury, illness or death occurring in a place of employment** or in connection with any employment to the local Cal/OSHA district office. A "serious injury or illness" is defined in 8 CCR 330(h) found at **www.dir.ca.gov/title8/330.html**.

What is the treatment for Valley Fever?

Although many people with Valley Fever do not require treatment, those with symptoms should seek medical attention. When Valley Fever is suspected, doctors can order specialized tests to confirm the diagnosis. If treatment is indicated, anti-fungal medications are available. Workers who develop severe or chronic infections may need to stay in the hospital.

It is especially important for people at risk for severe disease, such as people infected with HIV or those with weakened immune systems, to be diagnosed and receive treatment as quickly as possible. People with severe infections need to be treated because advanced Valley Fever can be fatal.

Summary of Controls to Minimize Workers' Dust Exposure and Risk of Valley Fever in Endemic Areas

Type of Control	Actions
Engineering and Work Practice Controls ➤ *to control dust at the source or isolate worker from exposure.*	Minimize exposure to outdoor dust: • Suspend (stop) work in dust storms or high winds. • Minimize the amount of digging by hand. Instead, use heavy equipment with operator in an enclosed, air-conditioned, HEPA-filtered cab. Continuously wet the soil before and while digging or moving the earth. Landing zones for helicopters and areas where bulldozers, graders, or skid steers operate are examples where wetting the soil is necessary. When digging in soil is required, train workers to reduce the amount of dust inhaled by staying upwind when possible.
Administrative Controls ➤ *to increase hazard awareness and knowledge of safe work practices and select safer work practices.*	Train workers and supervisors on: • Distribution of endemic areas • Symptoms and signs, and need to report to supervisor to obtain medical evaluation • People at highest risk of serious disease • Effective controls, including proper use of equipment.
Personal Protective Equipment ➤ *to decrease quantity of fungal spores inhaled.*	Provide respirators when digging or working near earth-moving trucks or equipment: • Powered air-purifying respirator (PAPR) with high efficiency particulate air (HEPA) filter or • Full-face respirator with particulate filter or • Half-mask respirator with particulate filter and • Implement a comprehensive respirator program including medical clearance, training, fit testing, and procedures for cleaning and maintaining respirators. Provide coveralls to prevent street clothes from being contaminated with fungal spores and then taken home.
Clean up ➤ *to decrease quantity of fungal spores inhaled.*	Provide lockers and require change of clothing and shoes at worksite so workers don't take dust and spores home. Wash equipment before moving offsite.
Medical care for disease recognition and prompt, appropriate treatment.	Contract with local medical clinics • Provide prompt evaluation and care • Make sure clinic has a protocol for evaluation, follow-up, and treatment of Valley Fever Make sure in-house physician is aware of work in Valley Fever endemic areas.

Valley Fever in the general population in California (*includes individuals exposed at work*):

- In 2011, 5123 people were diagnosed with new infections.
- The number of new Valley Fever cases reported in California increased dramatically in the past few years. In 2011, there were 20% more cases compared to 2010.
- Every year, about 1,430 people are hospitalized with Valley Fever.
- About 8% (8 out of 100) of people hospitalized with Valley Fever die due to the infection.

RESOURCES

FOR MORE INFORMATION

- **California Department of Public Health,** *"Coccidioidomycosis (Valley Fever) Fact Sheet"* **www.cdph.ca.gov/healthinfo/discond/pages/coccidioidomycosis.aspx** Available in English, Spanish, and Tagalog. Also see *Yearly Summary Report of Coccidioidomycosis in California.*
- **California Department of Public Health, Hazard Evaluation System and Information Service (HESIS).** HESIS answers questions about workplace hazards for California workers, employers, and health care professionals. Call **(510) 620-5817 or (866) 282-5516 (toll free in CA).** HESIS has many free publications available. To request publications, leave a message at **(510) 620-5717 or toll free (866) 627-1586**, or visit our website at **www.cdph.ca.gov/programs/ohb**
- **Centers for Disease Control and Prevention,** *"Coccidioidomycosis, Valley Fever"* **www.cdc.gov/fungal/coccidioidomycosis/.**
- **Centers for Disease Control and Prevention,** *"Increase in Reported Coccidioidomycosis-United States, 1998-2011,"* March 29, 2013 **http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6212a1.htm**
- **Injury and Illness Prevention Program.** This standard (California Code of Regulations (CCR) Title 8, Section 3203), requires employers to implement an injury and illness prevention program (IIPP). For links to publications on IIPPs, see **www.dir.ca.gov/title8/3203.html.**
- **Respiratory Protection.** This standard, CCR Title 8, Section 5144, requires employers to provide respirators when necessary to protect the health of employees. See **www.dir.ca.gov/title8/5144.html**.

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Edmund G. Brown Jr., Governor
State of California

Diana S. Dooley, Secretary
Health and Human Services Agency

Ron Chapman, MD, MPH, Director and
State Health Officer
California Department of Public Health

Marty Morgenstern, Secretary
Labor and Workforce Development Agency

Christine Baker, Director
Department of Industrial Relations

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