Stormwater Runoff Water Quality Science/Engineering Newsletter
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This issue of the Newsletter is devoted to a review of the current **nonpoint source (NPS) water quality management practices** that can be used to protect the designated beneficial uses of receiving waters for NPS runoff/discharges. While this Newsletter focuses on the runoff/discharges from irrigated agriculture and managed wetlands in the Central Valley of California, it is applicable to the development of management practices (BMPs) for many other areas.

Drs. G. F. Lee and A. Jones-Lee (2002) have recently completed a report, "Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges." The Executive Summary from this report is the focus of this Newsletter. This report provides a recommended approach for establishing technically valid, cost-effective water quality management practices for nonpoint source stormwater runoff/discharges. It also provides specific recommendations for developing water quality management practices for several potential pollutants typically associated with agricultural and urban runoff/discharges, including pesticide-caused aquatic life toxicity, nutrients, sediments, TOC, TDS, contact recreation sanitary quality, etc. A summary of these issues is presented in the attached Lee and Jones-Lee (2002) report Executive Summary. The complete discussion is presented in Lee and Jones-Lee (2002).

Recently, the Natural Resource Defense Council (NRDC, 2002) has coincidentally issued a report on water quality "BMPs" for Central Valley agriculture. That NRDC report provided information on potential water quality management practices that may be of value in controlling the water quality impacts of Central Valley agriculture stormwater runoff and tailwater discharges. Many of the references in the NRDC "BMP" report are the same as those provided in the Lee and Jones-Lee (2002) review of potentially appropriate agricultural management practices that was completed in mid-December 2002 for the California State Water Resources Control Board and Central Valley Regional Water Quality Control Board. There are some differences in the references listed and discussed by the two reports, with the result that the two reports compliment each other in addressing potential water quality management practices for Central Valley irrigated agriculture. However, the two reports come to significantly different conclusions regarding the approach that should be followed in implementing the water quality management practices. NRDC concluded that there is sufficient knowledge about the existing water quality management practices to immediately implement "BMPs." NRDC stated in its report,

> *"There is, as a consequence, no justification for further delay in implementation. For example, in instances where priority pollutants can be reduced or eliminated, there is no*

justification for delaying in order to precisely quantify the water quality benefits that will accrue."

Lee and Jones-Lee (2002) concluded that, while there are a variety of water quality management practices that have potential applicability to Central Valley irrigated agriculture, their efficacy and cost-effectiveness in the Central Valley agricultural setting are largely unknown. Lee and Jones-Lee recommended that a highly focused, systematic evaluation be made of the most promising water quality management practices for representative agricultural settings in the Central Valley. The results of that evaluation should be used to select the water quality management practice(s) that should be used in each type of Central Valley agricultural setting to achieve the water quality management goal in the most cost-effective manner. This conclusion is applicable to many other parts of the country where there is concern about developing NPS management practices.

Lee (2003) have developed comments on several technical issues raised in the NRDC report, as well as a discussion of the justification for the Lee and Jones-Lee (2002) conclusion that there is need for site-specific evaluation of potential water quality management practices in order to develop the appropriate approach for controlling the water quality impacts of agricultural stormwater runoff and irrigation tailwater/subsurface drainwater discharges in the Central Valley. The Lee (2003) comments on the NRDC report are available at www.gfredlee.com or by request from gfredlee@aol.com.

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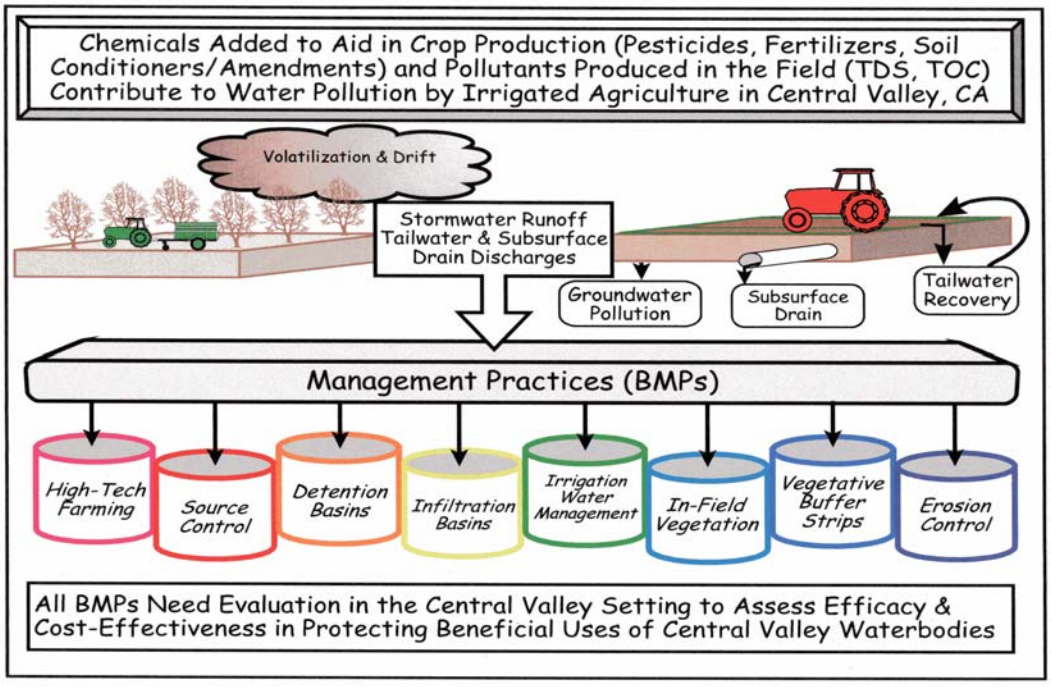
CALIFORNIA WATER INSTITUTE

Report TP 02-05

Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges



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Report to
State Water Resources Control Board and the
The Central Valley Regional Water Quality Control Board
Sacramento, CA

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DISCLAIMER

This publication is a technical report by staff of the California Water Institute to the California State Water Resources Control Board and the Regional Water Quality Control Board, Central Valley Region. No policy or regulation is either expressed or intended.

Disclosure Statement

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This project was conducted by Drs. G. Fred Lee and Anne Jones-Lee as employees of the California Water Institute, California State University, Fresno. In addition to the support provided to this project by the California Water Institute and the Central Valley Regional Water Quality Control Board, it was supported by G. Fred Lee & Associates, El Macero, California.

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California Water Institute
California State University, Fresno

The California Water Institute was started with seed money provided by the Proposition 13 Water Bond Measure, approved by voters in 2000. The Institute is housed at the California State University, Fresno.

The goal of the Institute is to provide a place where agricultural, urban, and environmental interests can be brought together in an unbiased, open, collaborative process to develop a shared vision of how to best utilize our water resources. It is the stated purpose of the Institute to work on collaborative solutions to pressing water issues facing the State. The staff of the Institute includes economists, chemists, crop water usage specialists, resource specialists, and environmental engineers. In addition, faculty at the California State University, Fresno, collaborate with the Institute in important research efforts.

Executive Summary

With increased attention being given to controlling the water quality impacts of chemical constituents present in stormwater runoff and tailwater discharges from irrigated agricultural land, there is need to apply best management practices (BMPs) to control the runoff/discharge of potential pollutants that are impairing the beneficial uses of the receiving waters for the runoff/discharge. The US EPA (2002) uses "management measures" rather than the term "BMPs" to describe control programs, based on the uncertainty as to what is the "best" management practice. In this review "management measures," "management practices," and "BMPs," are all used synonymously.

A review of the literature on agricultural water quality BMPs shows that there is limited quantitative information on the ability of various so-called "BMPs" that are sometimes advocated as treatment technology to reduce the concentrations of chemical constituents in agricultural land runoff/discharges nationally. This lack of information is particularly acute in the Central Valley of California, where, as discussed by Lee and Jones-Lee (2002a), there are potentially a dozen or so TMDLs that could be implemented in the San Joaquin River watershed over the next 10 years or so to control constituents that are present in agricultural land runoff/discharges. There is need to provide agricultural interests, the regulatory community and others, with quantitative information on potential water quality BMPs that could be applied to a particular type of agricultural land runoff/discharge situation to control one or more potential pollutants in the discharge/runoff to a specified degree in a cost-effective manner.

While it was not possible to develop a compilation of how various types of conventional agricultural runoff BMPs would be expected to control various types of agriculturally-derived pollutants in Central Valley runoff/discharge waters, information of this type for the same types of BMPs and constituents is provided in this report for urban stormwater runoff. The urban stormwater runoff water quality management field faces many of the same water quality problems as occur with agricultural stormwater runoff. Urban stormwater management BMP development is considerably advanced over agricultural water quality BMP development and, therefore, can provide guidance to the agricultural community on appropriate BMP development.

While the original purpose of this study was to provide overall guidance on the potentially effective BMPs for agricultural land runoff/discharges for the common potential pollutants such as pesticides, nutrients, and other constituents, the lack of information in this topic area necessitated a revision in the originally anticipated approach in developing this report. Rather than providing information on the potential effectiveness of vegetative areas and detention ponds, etc., for various types of agricultural runoff settings that occur in the Central Valley of California, the focus of this report became one of developing guidance on how to properly develop BMPs to control potential pollutants in agricultural land runoff/discharges. The potential pollutants that are derived from irrigated agricultural land runoff/discharges that are among those of greatest concern in the Central Valley are pesticides, nutrients, salts, sediments, and specific toxicants such as selenium and boron. While there are a number of other potential pollutants of concern, such as total organic carbon (TOC), the degree of understanding of their impacts and amounts derived from various agricultural sources is poorly understood. That type of information must first be obtained before BMPs to control their impacts can be developed.

Selenium, TDS, Boron

A special situation occurs in the Grasslands area of the Central Valley, where the discharge of selenium, total salts (TDS) and boron by irrigated agriculture is of concern in parts of the Mud Slough and Salt Slough watersheds in the San Joaquin River watershed. Agricultural interests in this area have investigated the agricultural practices that result in elevated selenium releases. They are associated with the management of subsurface drain water arising from a perched water table that results from the practice of irrigated agriculture in the area. The subsurface drains transport selenium from the perched groundwater to surface waters. The selenium associated with subsurface drain waters is being managed through water management techniques.

At this time, consideration is being given to various irrigation and stormwater runoff water management approaches for controlling the discharge of salts and some other potential pollutants derived from agricultural lands. This is an evolving area of concern related to complying with the TDS TMDL that is being adopted by the CVRWQCB.

Managed Wetlands

Substantial areas of the Central Valley are devoted to federal and state wildlife refuges and duck clubs. These areas are managed wetlands where the managers control water additions and releases. Water releases from these managed wetlands contain a variety of potential pollutants, such as TDS, total organic carbon (TOC), nutrients (N and P), and other constituents. It is possible that operators of managed wetlands for wildlife habitat will need to adopt altered water-management practices to control the adverse impacts of chemical constituents in the wetlands discharges.

The Sacramento-San Joaquin River Delta serves as the domestic water supply for about 22 million people in California. Water utilities that use Delta water as a water supply source experience water quality and water treatment problems due to constituents such as TOC, nutrients that develop into algae, and TDS that impair wastewater recharge. The San Joaquin River watershed and the Delta have been shown to be significant sources of pollutants that impair the use of Delta waters for domestic water supply purposes. There is need to understand the agricultural practices within the Delta watershed and the Delta that lead to excessive concentrations of pollutants that impair the use of Delta water for domestic water supply purposes, and develop management practices to control the constituents of concern at their source. At this time there is essentially no information on the control of TOC in agricultural and managed wetland stormwater runoff and discharges.

The growing of rice in the Sacramento River watershed has led to problems with adverse water quality impacts of chemicals (herbicides) used in rice farming in waterbodies that receive water releases from rice fields. BMPs were developed by the rice industry to control these water quality problems based on an understanding of the aquatic chemistry of the herbicides, which led to holding the rice field drainage water for a sufficient period of time to allow the chemicals added to the fields that were causing downstream water quality problems to decay sufficiently to control the chemical-caused water quality problems.

OP Pesticides

Since extensive work has recently been done on the potential BMPs that could be used to control the concentrations of organophosphate (OP) pesticides, such as diazinon and chlorpyrifos, in stormwater runoff from irrigated agriculture, a summary of this work and conclusions developed from it, as well as references to recently developed reports, are provided herein. It has been found that while there are a number of potential management practices that could reduce/eliminate the discharge of OP pesticides from agricultural lands, at this time there is a lack of quantitative information on the efficacy and cost of these management practices.

Sediments, Turbidity

The discharge of sediments associated with agricultural land erosion is an issue of particular concern in some areas of the Central Valley, especially on the west side of the San Joaquin River. Progress is being made in controlling erosion through improved agricultural practices as well as through the use of organic polymers (PAM).

Pathogens

Pathogen indicator organisms and human pathogens are receiving increased attention as a cause of water quality impairment for the use of waters for contact recreation or domestic water supplies. The US EPA is requiring that states adopt *E. coli* or enterococcus as a fresh-water indicator organism water quality standard to evaluate the suitability of a water for contact recreation. This will lead to greater monitoring of waterbodies for pathogen indicators such as *E. coli*. Such monitoring will likely show that agricultural lands are significant sources of these organisms. This in turn can lead to 303(d)-listed waterbodies for which management practices will need to be developed to control the discharges/releases of *E. coli* from agricultural lands. At this time there is limited understanding of the agricultural practices that lead to elevated concentrations of *E. coli* and therefore the management practices that need to be implemented to prevent the pollution of waterbodies by *E. coli* in stormwater runoff and tailwater discharges from agricultural activities.

DO Problems

The San Joaquin River Deep Water Ship Channel (DWSC) near Stockton, California, experiences low dissolved oxygen concentrations that violate water quality standards. This has led to the DWSC being listed as a Clean Water Act 303(d) impaired waterbody for which a TMDL must be developed to control violations of the DO water quality standard. Studies have shown that one of the major sources of oxygen demand for the DWSC is algae that develop in the San Joaquin River watershed based on nutrient discharges from agricultural lands. There is need to develop management practices that can be used to control nitrogen and phosphorus discharges from agricultural lands that develop into algae that are transported to the DWSC where they die and decompose, consuming oxygen in the process.

Nutrients

Excessive fertilization (eutrophication) is one of the most common and significant causes of impairment of beneficial uses of waterbodies. Excessive fertilization of waterbodies can have a significant adverse impact on a waterbody's water quality. As a result of the widespread occurrence of excessive fertilization of waterbodies, the US EPA has initiated development of chemical-specific numeric nutrient (nitrogen and phosphorus compounds) water quality criteria

designed to be the control objective for excessively fertile waterbodies. These criteria will be used to establish state water quality standards, where exceedance of the standard will be used to designate Clean Water Act 303(d) "impaired" waterbodies that will lead to the need to implement a TMDL to achieve the nutrient water quality standard. The US EPA has established 2004 as the date by which state regulatory agencies must have made significant progress toward adopting chemical-specific nutrient criteria/standards. By the mid 2000s, there could be a large number of additional waterbodies in the Central Valley of California and nationally, beyond those already classified as impaired due to excessive concentrations of nutrients, that need to have TMDLs developed and implemented in order to satisfy nutrient control requirements.

While, until now, nutrient management programs have largely focused on treating domestic and industrial wastewater discharges for nutrient removal, in the future, nonpoint runoff/discharges will also have to be treated/managed to prevent excessive fertilization of the waterbodies receiving the runoff/discharges. The current and future nutrient control programs for irrigated agriculture stormwater runoff/tailwater discharges will create a significant demand for reliable information on BMPs to control nutrient discharges in a technically valid, cost-effective manner.

At this time there is limited information on the efficacy and cost-effectiveness of various stormwater runoff/tailwater discharge water quality BMPs, such as vegetative cover, buffer strips, grassy swales, detention basins, etc, that are often listed as water quality BMPs that can be used to control nutrients and, for that matter, other constituents in agriculturally-derived stormwater runoff/discharges from irrigated and non-irrigated agriculture in the Central Valley of California. Central Valley irrigated agriculture, in many respects, is significantly different from agriculture in other parts of the country. This difference arises from the significantly different climate in this area where precipitation occurs for a few months each winter. This necessitates crop irrigation, which leads to irrigation field (tailwater) discharges during the late spring and summer. The tailwater discharges have a significantly different potential pollutant composition than stormwater runoff. There is need for guidance on how to properly develop nutrient control BMPs that will control the nutrient runoff/discharges in the Central Valley to a specified degree in a cost-effective manner. This report provides guidance on approaches that could be used to develop appropriate nutrient management programs/BMPs for agricultural runoff/discharges.

The development of technically valid, cost-effective waterbody excessive fertilization management programs is technically different than most other pollutant control programs. Excessive fertilization problems can occur long periods of time after nutrient release/discharge and at considerable distances downstream. This makes directly relating nutrient releases/discharges to impacts on water quality more difficult. Another complicating factor in developing nutrient management programs is that the impacts of excessive fertilization are often subjective and are dependent on the public's response to the aquatic plant biomass in the waterbodies of the area. The often remote but real connection between nutrient concentrations/ loads in discharges from an area and the social impact in another downstream area can readily cause the US EPA's proposed chemical-specific numeric nutrient criteria to be technically invalid. Because of the complexity of excessive fertilization, the development of a technically valid, cost-effective nutrient management program often requires a substantially larger

information base on the characteristics of nutrient releases and downstream waterbodies than is typically needed for management of toxic pollutants.

The approach that should be followed in developing a BMP to control nutrient runoff/discharges is similar to the approach that is used to develop a nutrient control program to meet a TMDL requirement to control excessive fertilization of a waterbody. In developing the appropriate nutrient criteria BMP control objective, it is suggested that the TMDL development approach is an appropriate approach to follow. This approach involves the following steps:

- Developing a problem statement − i.e., what is the excessive fertilization problem of concern?
- Establishing the goal of nutrient control (i.e., the desired eutrophication-related water quality).
- Determining nutrient sources, focusing on available forms.
- Establishing linkage between nutrient loads and eutrophication response (modeling).
- Developing and initiating a Phase I nutrient control implementation plan to control the nutrients to the level needed to achieve the desired water quality. This will require the selection, implementation, and evaluation of various nutrient control methodologies (BMPs).
- Monitoring the waterbody for three to five years after nutrient control is implemented to determine whether the desired water quality is being achieved.
- If not, initiate a TMDL implementation Phase II where, through the monitoring results, the load-response model is improved and thereby able to more reliably predict the nutrient loads that are appropriate for the waterbody of concern desired water quality.

This approach is an iterative approach, where, over a period of at least five to possibly 15 years, through two or more consecutive phases, it will be possible to achieve the nutrient-related desired water quality and thereby establish the allowable nutrient loads which can be translated to in-waterbody concentrations and, therefore, the nutrient criteria that are appropriate for the waterbody. This information can then be used to develop appropriate BMPs for the location and type of agriculture being practiced in the area of concern. Information on several of these issues is presented in this report.

Because of the importance of the US EPA's efforts to develop nutrient criteria to regulate nutrient discharges, which in turn will control the development of appropriate BMPs, this report includes a discussion of the problems with the US EPA's current approach for developing nutrient criteria, as well as a recommended approach for determining the allowable nutrient discharges from a source that will protect the eutrophication-related water quality of downstream waterbodies. The US EPA has adopted two approaches for developing nutrient water quality criteria/standards. One of these is the Agency's "default" approach, where emphasis is on assessing the pre-cultural nutrient concentrations in a waterbody as a basis for establishing the allowable nutrient concentrations. The US EPA's proposed approach for developing default nutrient criteria is recognized as technically invalid by many who are familiar with how nutrients impact water quality. The Agency's approach could result in massive expenditures for nutrient control from point and nonpoint sources beyond that which is needed to achieve the desired nutrient-related beneficial uses of a waterbody. Further, this approach could be significantly

detrimental to the aquatic life (fisheries)-related beneficial uses of waterbodies, as a result of adversely impacting the trophic structure of waterbodies.

The Agency's other proposed approach for developing nutrient criteria/standards potentially involves the regulatory agencies and the regulated community, as well as others interested, working together to develop site-specific nutrient criteria/standards for a waterbody or group of similar waterbodies. According to the US EPA, the site-specific criteria development approach must be "scientifically defensible." The Agency; however, does not define what that means. This report discusses recommended approaches for developing site-specific nutrient criteria that will protect the nutrient-related beneficial uses of a waterbody without significant unnecessary expenditures for nutrient control, through the implementation of BMPs. The nutrient control section of this report is based on 42 years of the senior author's experience in investigating and managing excessive fertilization of waterbodies in the US and many other countries. Background information on these issues is provided on the authors' website, www.gfredlee.com.

Organochlorine Pesticides, PCBs, Dioxins/Furans

Eleven waterbodies in the Central Valley are listed as Clean Water Act 303(d) impaired because of excessive bioaccumulation of organochlorine "legacy" pesticides, PCBs or dioxins/furans in edible fish tissue. These chemicals are called OCls in this report. The legacy pesticides include DDT, chlordane, dieldrin, toxaphene and other chlorine-based pesticides that were banned 10 or more years ago because of adverse impacts on birds and other wildlife. These pesticides are regulated as human carcinogens. The OCls tend to bioaccumulate in edible fish tissue, and therefore are a threat to those who use as food fish containing elevated concentrations of OCls. They also tend to be strongly sorbed by soils and aquatic sediments.

Lee and Jones-Lee (2002b) have recently reviewed the existing database on OCls in Central Valley waterbody fish and other aquatic organisms. They have recommended an approach for managing the excessive bioaccumulation of the OCls in edible Central Valley fish. The recommended approach involves determining the amount of the OCls that are contributed to the 303(d)-listed waterbodies from the waterbodies' watersheds. If current stormwater runoff/discharges are still contributing OCls to the waterbody then management practices should focus on controlling the OCl-containing soils at their source. The other component of the recommended OCl management program is to identify the in-waterbody sediments that are contributing OCls to fish that are bioaccumulating excessive OCls. This management practice could require removal/burial of the OCl-containing sediments.

Sediment Toxicity

It is likely that aquatic sediment toxicity will be found in Central Valley waterbodies that is due to discharges of pesticides and/or nutrients derived from irrigated agriculture runoff/discharges. Management of sediment toxicity will require identification of the cause of the toxicity and then its origin. This can lead to the development of appropriate management practices to control the sediment toxicity.

Science of BMPs

Information is presented in this report on developing management practices based on the basic physics, chemistry, hydrology and biology that govern the mechanisms of potential pollutant removal. It is suggested that those developing agricultural runoff/discharge management practices become familiar with the water and wastewater treatment methodologies as well the development of urban and highway stormwater runoff BMPs. Following this approach would lead to improved agricultural BMPs.

Integrated Approach

It is recommended that the water quality stakeholders (agricultural interests, regulatory agencies, environmental groups, and the public) in each of the major tributaries of the San Joaquin River and Sacramento River watersheds, as well as the mainstem of each river, organize an integrated water quality monitoring program to define the potential water quality problems in each watershed and downstream thereof that are caused by constituents derived from the watershed. This monitoring program should follow the approach recommended by Lee and Jones-Lee (2002c) for conducting a comprehensive watershed-based NPS water quality evaluation. Also, the stakeholders in various parts of the Delta (south, mid, northeast) should conduct comprehensive water quality monitoring programs in their part of the Delta. The focus of these monitoring programs should be on determining whether regulated potential pollutants exist in the State's waters within the watershed at concentrations that exceed CVRWQCB water quality objectives. An Evaluation Monitoring (Jones-Lee and Lee, 1998) approach should be used which focuses on determining the impacts of chemical constituents and pathogen-indicator organisms on the beneficial uses of waters within the watershed.

The results of these monitoring programs should be used to define the constituents that cause significant water quality use impairment in the watershed or parts thereof. Based on this information, the stakeholders in the watershed should organize an integrated management practice (BMP) evaluation program to determine the degree of control of the constituents of concern that can be achieved at various costs. This information should then be used by the stakeholders to formulate a technically valid cost effective NPS and point source management program to protect the designated beneficial uses of the waterbodies in the watershed as well as downstream.

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