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SOURCES OF SEDIMENT-INDUCED REDUCTIONS IN WATER QUALITY APPRAISED FROM CATCHMENT ATTRIBUTES AND LAND USE

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ABSTRACT

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Throughout the world, mountainous regions provide the principal sources of water supply. The usefulness of the water supply depends in part on the quality of the water, which is most often dependent on the sediment concentration. In periods of floods and from areas with unstable terrain, the sediment concentration may be naturally high. On the other hand, man's activities may create unstable areas and thereby decrease the quality of water from catchments. Catchments themselves give us the best means of determining both the natural and the man-accelerated sediment concentration of streamflow from mountain catchments. Suspended-sediment measurements from 61 catchments in California were used to relate suspended-sediment discharge to ten catchment attributes. Suspended sediment was normalized by using long-term streamflow of each catchment. Factor analysis showed no confounding among the ten attributes: regression on principal components gave an explained variance; land-use variable 30%; streamflow and rain—snow frequency 14%; geology, including faults, 11%; and tributary channel slope the other 3%. Catchment shape was the least important variable, with palm-shaped catchments having only 13% more sediment discharge than dendritic-shaped catchments. *Differences in landslide classes produced the greatest differences in sediment discharge:* sediment discharge from landslide class *6* was 12 times that from class *1*. A separate analysis gave a basis for calculating landslide classes from catchment attributes. The use of results are illustrated in separating natural from accelerated sediment discharge and sediment concentration in the Redwood Creek Basin.

INTRODUCTION

To estimate sediment discharge from catchments, or the expected contribution of parts of catchments to sediment discharge or sediment induced reductions in water quality, the sources and causes of sediment need evaluation. By using measured suspended sediment concentration and streamflow frequencies from many catchments with diverse watershed attributes, it is possible to evaluate the independent contribution of space variation of sediment discharge from watersheds. Different attributes produce different amounts of suspended-sediment discharge so different parts of watersheds with those differences in attributes may be reasoned to also contribute those different amounts of sediment. The problem is one of evaluating the quantitative effect of differences in attributes to differences in sediment discharge. Principle-components analysis has proven to be powerful statistical tool in testing independence among the attributes to be evaluated and evaluating their quantitative relation to deposition. The regression results obtained permit prediction of hazard land areas with different attributes, and estimating the effects on sediment deposition of changes in land management. Suspended-sediment measurements from 61 northern California watersheds were utilized in relating average normalized suspended-sediment discharge to ten watershed attributes.

NORMALIZING SEDIMENT DISCHARGE

So that sediment measurements from a watershed for a single year or for a short period of years may be more representative of long-term expectancy of sediment discharge, the measurements must be normalized. One technique of accomplishing normalization is known as the "flow duration—sediment discharge method". Basically the method utilizes, for each year or period of years, the relationship of sediment concentration to stream discharge. Sediment discharge is the product of sediment concentration and streamflow; however, instead of using each year's or period streamflow, the long-term frequency of streamflow is used; giving yearly or period sediment discharge expected under representative long-term flow conditions. Perhaps a dozen people have "invented" this procedure, including the author (Anderson, 1954). That application recognized that water quality was also of interest, so the method incorporated the computation of frequencies of sediment concentration by classes from the same data. The method is illustrated by the relationship of sediment concentration to stream discharge for the Eel River and the streamflow duration for that stream. A typical computation is shown in Table I, yielding sediment discharge for a year and the distribution of both frequency of sediment concentrations by percent of time and by percent of volume of the expected long-term flow. Application of the method gives rather consistent year-to-year estimate of sediment discharge from individual yearly measurements of sediment concentration and associated streamflow (Wallis and Anderson, 1965). However, catastrophic events have been found to change watershed conditions at least temporarily (Anderson, 1970), so sediment data utilized in the study reported here were taken from periods in which such catastrophic events had not disturbed basic relationship between sediment concentration and discharge. Typically, the average of three years of estimation of sediment discharge were used as the measured suspended-sediment discharge; these are given in the last column of Table II.

TABLE I

Watershed suspended-sediment analysis based upon flow duration and discharge relationship, Eel River at Scotia, USGS No. *11-4770*, 1969 sediment concentration sampling

Mean flow (cfs*1)	Frequency (%)	Amount flow	Number of sediment samples	Sediment concentration (ppm)	Total load
120	10.00	0.002	11	0	0.00
200	10.00	0.003	11	3	0.01
335	10.00	0.005	11	8	0.04
570	10.00	0.008	6	16	0.13
1,280	10.00	0.018	13	40	0.72
2,525	10.00	0.036	0	82	2.92
3,825	10.00	0.054	1	126	6.81
5,900	9.00	0.075	15	196	14.73
8,700	6.00	0.074	9	618	45.64
12,500	5.00	0.088	6	738	65.27
18,500	3.00	0.078	8	927	72.84
28,000	3.00	0.119	10	1,228	145.91
43,000	2.00	0.122	13	1,701	207.04
64,000	1.00	0.091	8	2,365	214.15
93,000	0.50	0.066	3	3,281	215.86
125,000	0.20	0.035	2	4,291	151.81
160,000	0.15	0.034	2	5,397	183.28
210,000	0.08	0.024	2	6,976	165.84
265,000	0.03	0.011	0	8,714	98.02
320,000	0.02	0.009	0	10,451	94.64
380,000	0.02	0.011	0	12,346	132.77
Total	100	0.963	131		1,818.4

(mean flow) = 7067 cfs = ~200 $m^3 s^{-1}$.
(adjusted mean sediment concentration) = 1818.4/0.963 = 1890 ppm.
(total suspended sediment load) = 13.14 ton*2.
(suspended sediment load) = 4,221 ton $mi.^{-2}$.
(suspended sediment load) = 1,478 t km^{-2}.
(suspended sediment concentration) = 3.5828 + 0.03384(flow), $Q < 7067$ cfs.
(suspended sediment concentration) = 343.1 + 0.03159(flow), $Q \geqslant 7067$ cfs.

Water quality (ppm)

	<5.5	5.5–12	13.0–27.0	28.0–72.0	73.0–142	>142
% samples	6.9	16.0	13.7	1.5	6.1	55.7
% days	20.0	10.4	9.4	12.8	8.2	39.0
% water	0.5	0.5	0.8	2.8	3.1	92.4

*1 1 cfs = 1 $ft.^3 s^{-1}$ = 0.02832 $m^3 s^{-1}$.
*2 1 ton = 1 short ton = 0.9078 t = 907.8 kg.

TABLE II

Catchment attributes and normalized suspended-sediment discharge, northern California

Name	USGS No.	Area (km^2)	AVLS	FLTS	CV	SL	USED	IGS	L1	RRA	MAQ	F_{10}	SED
Sagehen Cr.	*10-3435*	28	2.0	0	44	140	0	16	0	27	11.3	0	3
Piru Cr.	*11-1100*	1,119	3.9	266	51	182	31	2	0	88	1.6	141	322
Sespe Cr.	*11-1115*	133	4.0	378	47	159	98	5	0	82	3.0	0	287
N. F. Matilija Cr.	*11-1160*	40	4.2	757	41	250	82	18	0	97	5.8	10,144	481
Salispuedes Cr.	*11-1325*	122	3.9	42	55	102	76	102	0	100	2.0	0	188
Cuyama Rv.	*11-1370*	2,362	4.0	93	55	273	76	399	0	86	0.2	0	256
Nacimiento Rv.	*11-1488*	363	2.8	98	46	170	52	12	0	100	12.6	16	215
San Francisquito Cr.	*11-1645*	98	3.7	233	40	140	80	9	0	100	6.0	0	154
Walnut Cr.	*11-1835*	199	2.9	137	47	100	85	103	0	100	2.0	280	286
Kern Rv.	*11-1870*	2,613	2.0	40	50	278	0	87	0	31	11.8	106	190
Merced Rv.	*11-2645*	469	2.0	0	52	192	0	1	0	9	20.3	6	4
Cosumnes Rv.	*11-3345*	1,111	2.0	20	44	104	0	9	111	84	11.5	311	33
Cosumnes Rv.	*11-3350*	1,391	2.0	53	32	104	0	9	89	87	9.9	183	40
Cosumnes Rv.	*11-3360*	1,891	2.0	42	47	83	10	13	66	90	8.7	327	106
Sacramento Rv.	*11-3420*	1,106	3.1	25	51	233	0	0	145	72	27.5	80	29
McCloud Rv.	*11-3680*	1,570	2.2	16	46	170	0	0	0	71	30.3	17	102
Clear Cr.	*11-3710*	298	2.1	0	60	197	0	3	0	86	21.1	574	36
M. F. Cottonwood Cr.	*11-3744*	645	3.2	44	40	223	46	12	0	92	9.8	672	120
Cottonwood Cr.	*11-3760*	2,448	3.0	55	44	191	24	24	0	91	9.4	905	178
Battle Cr.	*11-3765*	938	1.8	14	37	81	3	1	0	74	13.7	98	16
Elder Cr.	*11-3795*	241	4.4	201	45	272	33	0	44	70	11.3	281	189
Thomes Cr.	*11-3820*	502	5.0	30	39	265	0	11	0	73	15.3	47	992
Grindstone Cr.	*11-3865*	404	4.8	44	47	252	25	12	141	85	10.8	325	1,006
Last Chance Cr.	*11-3914*	219	2.0	61	33	123	0	22	0	39	4.5	0	84
Big Grizzly Cr.	*11-3915*	116	2.0	0	46	109	0	27	0	46	9.9	0	45
Indian Cr.	*11-4015*	1,932	2.0	105	47	158	5	6	0	53	7.9	169	88
Castle Cr.	*11-4139*	10	2.0	0	57	158	0	52	0	20	40.0	0	82
Castle Cr. (logged)	*11-4139*	10	2.0	0	57	158	0	52	391	20	40.8	0	280
N. F. Cache Cr.	*11-4515*	513	5.9	105	55	203	4	14	0	96	9.5	1,710	244
Bear Cr.	*11-4517*	251	3.7	177	50	129	0	53	0	99	5.2	297	289
Napa Cr.	*11-4560*	210	2.8	0	44	180	7	6	0	100	11.6	30	215
Sonoma Cr.	*11-4585*	161	3.4	17	44	191	24	47	0	100	10.3	47	162
Russian Rv.	*11-4610*	258	3.8	59	43	133	22	89	22	99	19.0	1,547	850
E. F. Russian Rv.	*11-4620*	269	3.8	47	35	170	5	71	0	99	11.0	652	384
Big Sulfur Cr.	*11-4632*	213	6.0	299	43	165	0	109	0	97	23.6	1,601	1,099
Dry Cr.	*11-4652*	420	5.0	158	47	142	3	179	44	100	17.8	580	650
S. F. Casper Cr.	*11-4680*	4	4.0	0	49	103	100	0	0	100	15.5	0	89
N. F. Casper Cr.	*11-4681*	5	4.0	0	49	146	100	0	0	100	15.0	0	47
Outlet Cr.	*11-4722*	417	5.4	55	47	129	12	83	63	98	25.1	960	277
Eel Rv.	*11-4725*	922	5.8	38	46	193	0	68	61	97	15.0	1,586	1,183
Black Butte Rv.	*11-4729*	420	5.5	61	45	199	0	18	425	74	18.0	38	2,055
M. F. Eel Rv.	*11-4730*	951	5.6	51	47	180	0	8	28	69	31.2	63	1,414
Williams Cr.	*11-4731*	79	6.0	0	43	239	0	14	0	90	45.0	0	772
Short Cr.	*11-4736*	39	6.0	0	46	188	0	28	0	96	22.0	503	385
Mill Cr.	*11-4737*	248	4.8	10	41	114	33	31	0	96	14.9	330	627
M. F. Eel Rv.	*11-4739*	2,015	5.5	41	46	206	2	19	98	80	30.7	56	1,439
Eel Rv.	*11-4740*	3,836	5.9	39	46	197	15	31	66	80	21.4	727	1,232
Hulls Cr.	*11-4744*	67	6.0	76	53	178	0	43	0	87	44.5	0	214
S. F. Eel Rv.	*11-4755*	114	4.7	0	50	121	0	8	792	98	45.5	1,830	518
S. F. Eel Rv.	*11-4765*	1,391	4.8	84	52	195	7	38	811	98	36.3	639	1,747
Eel Rv.	*11-4770*	7,317	5.5	42	41	196	2	41	574	90	24.7	442	1,719
Van Duzen Rv.	*11-4785*	559	6.0	40	50	184	1	48	2,165	89	39.2	41	2,121
Mad Rv	*11-4805*	360	5.7	151	47	231	0	56	0	84	23.6	39	260
Mad Rv.	*11-4810*	1,254	5.9	178	63	215	2	32	900	90	28.7	67	995
Shasta Rv.	*11-5175*	1,751	2.4	0	43	197	0	38	0	74	2.7	141	4
Scotts Rv.	*11-5195*	1,645	2.9	17	46	307	0	18	172	68	9.5	556	98
Trinity Rv.	*11-5255*	1,883	3.0	54	40	313	3	9	0	65	24.0	8	68
Weaver Cr.	*11-5258*	125	3.9	102	38	260	45	2	0	85	13.0	0	225
N. F. Trinity Rv.	*11-5265*	391	3.9	169	44	294	3	26	0	70	31.6	16	113
S. F. Trinity Rv.	*11-5290*	2,328	4.3	87	42	259	3	8	0	83	17.6	158	161
Trinity Rv.	*11-5300*	7,376	3.8	84	48	289	3	9	0	76	21.5	123	279
Mean		986	4.0	82	45	184	18	37	118	80	17.5	483	454

As may be seen, the sediment discharge varied widely between catchments from 4 to 2100 (t km^{-2} yr.$^{-1(*)}$).

WATERSHED ATTRIBUTES

To determine the sources and causes of the wide variation in sediment discharge among catchments, the sources and causes were expressed as variables and the value for each variable was determined for each catchment. Aerial photographs were used to determine the land-use and condition variables, U.S. Geological Survey topographic maps were used to obtain stream slope and catchment shape, State of California (1966) geologic maps were used to obtain geology, and geologic faults, streamflow measurements were from *U.S. Geological Survey Water Supply Papers*, rain—snow frequency

TABLE III

Suspended-sediment model, coefficients, units, means, and standard deviation of variables

Symbol	Definition
log SS = −0.326	regression constant, for suspended sediment in t km^{-2} yr.$^{-1(*)}$, mean log SS = 2.32, s.d. = 0.625
+0.214 AVLS	average landslide class from map by Radbruch and Crowther (1973), mean = 3.88, s.d. = 1.39
+ 0.294 log IGS	composite interaction variable made up of percent slope times percent grassland area, in % X %/10, mean = 1.227, s.d. = 0.577
+0.139 log L1	area classed as logged with roads predominately in draws, in m^2 ha^{-1}, mean = 0.754, s.d. = 1.088
+0.185 log USED	area of unconsolidated sedimentary rock types, in %, mean = 0.709, s.d. = 0.731
+0.306 log RRA	relative rain storm vs, snow frequency (Anderson and Wallis, 1965), in %, mean = 1.881, s.d. = 0.192
+0.355 log MAQ	mean annual streamflow, in l s^{-1} km^{-2} mean = 1.176, s.d. = 0.316
+0.087 log FLTS	length of geologic fault zones per unit area of watershed, in m km^{-2}, mean = 1.446, s.d. = 0.814
+0.297 log SL	slope of streams of 1500-m mesh length, in m km^{-1}, mean = 2.241, s.d. = 0.145
+0.010 log F_{10}	area of forest fires in the ten years prior to sediment measurements, m^2 ha^{-1}, mean = 1.770, s.d. = 1.135
−0.345 log CV	coefficient of variation of basin flowpath lengths (Wallis and Anderson, 1965), with path lengths as suggested by Busby and Benson (1960), unitless, mean = 1.672 s.d. = 0.055

* Metric tons per square kilometer per year.

of storms were obtained from special relationships previously established (Anderson and Wallis, 1963), and a special *U.S. Geological Survey Map* of slide potential was used for that variable (Radbruch and Crowther, 1973). Values of the variables for the 61 catchments are given in Table II and the definitions of the variables are given in Table III, together with the means, standard deviations, and the units in which the variables were expressed.

ANALYTICAL METHODS

The relation of suspended sediment discharge to catchment attributes, streamflow and land-use variables was studied by use of this general model:

$$\text{(sediment discharge)} = f[\text{(topography), (geology), (forest use and condition), (streamflow), (rain—snow frequency), (landslides), (geologic faults)}] \quad (1)$$

The analysis technique used was principle-components analysis consisting of a factor analysis of the correlation matrix, varimax rotation of the factors, and regression (Wallis, 1965).

FACTOR ANALYSIS RESULTS

The factor analysis showed no confounding among the ten variables. The contribution to explain variance in suspended-sediment discharge of each of the factors is shown in Table IV.

TABLE IV

Contribution of watershed factors to explained suspended-sediment discharge

Factor	Explained variance (%)	Factor	Explained variance (%)
Landslide	31	Streamflow	6
Steep grasslands	11	Topography	4
Poor logging	9	Forest fires	2
Geology	8		
Rain—snow frequency	6	Total	73

REGRESSION RESULTS

The regression model selected consisted of a log transformation of all variables except the landslide class. Regression was performed by using the

TABLE V

Range of data and extreme effects (if 100% of a catchment were in that class) for each variable in the suspended sediment discharge regression model

Variable	Multiplies sediment	
	range of data	maximum effect
Steep grasslands	2.73	12.9
Landslide potential	4.31	11.7
Watershed steepness	1.36	7.0
Rain—snow frequency	1.52	4.0
Streamflow volume	2.22	3.8
Logging	2.94	3.6
Watershed shape	1.69	3.2
Unconsolidated sediment	2.30	2.4
Geologic faults	1.65	2.0
Forest fires	1.08	1.1

61 measurements of average suspended sediment discharge and the associated ten catchment attributes. The ten variable regressions had a standard estimate of 0.359 log units and an explained variance of 73%. The regression equation and definition of variables are given in Table III, with the regression coefficients giving the quantitative relationship between each variable and the suspended-sediment discharge. The quantitative effects of each variable may be illustrated by showing the effect of the range in the data analysis and also the extreme effect if 100% of a catchment were in that class (Table V). The regression results add quantitative evaluation of several important variables not reported previously by Wallis and Anderson (1965) and by Anderson (1975). However, the coefficient for logging in this model excludes the effect of roads on sedimentation as part of the logging effects. Detailed evaluations of roads of different standards, in different locations in catchments, and in areas of steep slopes are given in Anderson (1975).

LANDSLIDE POTENTIAL

Because of the importance that the landslide map may have in predicting susceptibility of an area to extreme sediment discharge, the definition of and method of compilation of that map need specification. Radbruch and Crowther (1973) say:

"Data on slope, precipitation, and geologic units — major factors contributing to landslide — were generalized and plotted on maps for the entire State (California), which were then evaluated and combined. The resulting map units were subsequently modified by consideration of (1) other factor contributing to landslides; (2) information gained through correspondence or conversation with persons working on geologic mapping, some of it unpublished, in scattered parts of California. and (3) reconnaissance on-the-spot checking in the field, both on the ground and from the air. The map units, therefore, indicate only the estimated relative amount of area covered by landslides for each map unit."

TABLE VI

Contribution of watershed factors to explained landslide class

Factor	Explained variance (%)	Factor	Explained variance (%)
Relative rain area	22.3	Roads	2.3
Mean annual streamflow	11.2	Shape	1.5
Slope of tributary streams	6.2	Other	0.5
Steep grasslands	6.0		——
Faults	4.4	Total	57.6
Poor logging	3.2		

Although no quantitative relationship between the classes numbers and amounts of landslides were implied, an analysis of the landslide classes taken as independent variables indicated a progression from low to high coefficients for classes *1—6*. [This was in contrast with the lack of a consistent progression found in the analysis of reservoir sedimentation previously reported (Anderson, 1975).] The approximate linear progression of the effect on suspended-sediment discharge for classes *1—6* justified the use of *average* landslide class for a catchment as the single variable reported here.

As independent analysis was made of the relationship of average landslide class in watersheds to the catchment attributes as a possible clue to how future landslide maps might be prepared. The factor analysis showed the relationship of the explained variation in landslide classses to the various factors (Table VI).

The equation to predict landslide potential was obtained by regressing the average landslide class (AVLS) for the 61 catchments against six of the variables of Table III, then adjusting for the proportion of each geologic rock types in an area. The equation was:

$$\begin{aligned} \text{AVLS} = {} & -11.44 + 3.90 \log \text{RRA} + 1.68 \log \text{MAQ} + 2.21 \log \text{SL} \\ & + 0.59 \log \text{IGS} + 0.23 \log \text{FLTS} + 0.11 \log \text{L1} \\ & + 1.5\,(\text{Franciscan rocks}) + 0.2\,[(\text{ultrabasic, metamorphic}), \\ & \text{or (Tertiary sediment rocks)}] - 0.3\,(\text{Mesozoic rocks}) \\ & - 2.0\,[(\text{granitics, Precambrian sediments}), \\ & \text{or (volcanic rocks)}] \end{aligned} \qquad (2)$$

The importance of the streamflow and rain area variables in predicting landslides is of particular interest in view of Radbruch and Crowther's (1973) reporting of:

"lack of correlation between number of landslides and amount of precipitation"

Some of the broad geologic rock types, such as the Tertiary sediments, show wide variation in landslide potential: more detailed characterization of the geology is needed. It is beyond the scope of this paper to explore further the prediction of landslide potential, but the classification used here was found to be important in predicting sediment discharge. The Radbruch and Crowther map was a useful first attempt at evaluation of the landslide potential; the relations of eq. 2 is an extension of their classification in the form of quantitative evaluation of some important variables in landslide prediction.

AN APPLICATION — REDWOOD CREEK BASIN

One of the problems in evaluating sedimentation for any catchment is the natural or so-called baseline of sediment expectation from the catchment. This baseline rate of sedimentation has been considered as the sedimentation rate from which management decisions for needed improvement or allowed increase in sedimentation may be evaluated. We may calculate this baseline, as being the expected sediment discharge from a catchment in the absence of any land use of disturbance such as conversion of forests or brushlands to grass, logging, or forest fires.

The present author has selected for an illustration a catchment of current management controversy between logging vs. protection of the Redwood Park from possible sediment damage. The catchment is the Redwood Creek basin in north coastal California (drainage area 720 km^2). The natural or baseline sediment potential is calculated from the values of the landslide potential, faults, shape, slope, geology, rain area, and streamflow for the catchment, with the coefficients of Table III being applied. The resultant expected average annual sediment discharge is 297 t km^{-2}. Similarly, the average natural sediment discharge for the 61 catchments of Table VII is 69 t km^{-2} $yr.^{-1}$.

TABLE VII

Comparison of natural and present sediment discharges and average sediment concentrations

Condition	Sediment discharge (t km^{-2} $yr.^{-1}$)	Average sediment concentration (mg l^{-1})
Natural:		
Average all catchments	69	125
Redwood Creek Basin	297	220
Present:		
Average all catchments	454	854
Redwood Creek Basin	2,540	1,900

So the Redwood Creek basin is high in its natural sediment expectancy, 4.3 times as high as the average catchment of this study.

The land use and disturbance is also high. We can calculate the expected effects of the uses by applying the coefficients of Table III to the steep grasslands (IGS), the logging (LL), the past forest fires (F_{10}), to give present expected sediment. The comparison of natural and present sediment discharges and average sediment concentrations are given in Table VII. The sedimentation under present conditions in Redwood Creek Basin 2,540 is the average for the three years of measurement 1971—1973. The calculated sedimentation is similar, 2250 t km^{-2} $yr.^{-1}$. We see that in the Redwood Creek Basin, both the natural rate of sedimentation and the increase in sedimentation associated with present land use are higher than average. Presumably more than average care will be needed in management for sediment control in the basin.

CONCLUSIONS

Both natural land attributes, such as slope, geology and rainfall, and man-induced modifications of the lands resistance to erosion contribute to sedimentation from catchments. The individual contributions may be quantified by the analysis of measured sediment discharge from catchments, inventory of associated catchment attributes, and characterization of the degree and types of land use. In areas of high rainfall and steep terrain, landslides may be a major contributor to sedimentation hazard and to the result effects of land use on sediment production and reduced water quality resulting from sediment. The relationships found in this study have direct application to evaluating sedimentation problems and control in northern California, and may give some first approximations to evaluations in other areas.

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AQUATIC TOXICITY OF FORTY INDUSTRIAL CHEMICALS: TESTIN IN SUPPORT OF HAZARDOUS SUBSTANCE SPILL PREVENTION REGULATION

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ABSTRACT

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The U.S. Environmental Protection Agency is presently developing hazardous su stance spill regulations to help prevent water pollution. Aquatic animal toxicity data a used as criteria for the designation and categorization of substances as hazardous, ev though this type of data is not available for many industrial chemicals. Static 96-hr. to icity tests were conducted with 40 such chemicals to provide basic toxicity data f regulatory decision making. Thirty-two of the 40 chemicals tested were hazardous aquatic life as determined by 96-hr. LC_{50}'s less than or equal to 500 mg/l. All 40 chen cals were tested with the fresh-water fathead minnow, *Pimephales promelas*, and t chemicals were also tested with the salt-water grass shrimp, *Palaemonetes pugio*.

INTRODUCTION

The U.S. Environmental Protection Agency (E.P.A.) is charged wi attaining a national water quality which provides for the protection ar propagation of fish, shellfish, and wildlife, and allows safe public recreati in and on the waters. Under provision of the U.S. Federal Water Polluti Control Act Amendments of 1972, additional regulations were recent passed which specifically protect the nation's waterways from dischar (accidental or intentional) of substances hazardous to aquatic life (U. Federal Register, 1978). These hazardous substance spill prevention reg lations were divided into four parts: (1) Part *116* — for designation of su stances as hazardous based on aquatic animal toxicity and potential f discharge; (2) Part *117* — for determination of the removability hazardous substances after discharge; (3) Part *118* — for determination the harmful discharge quantity based on aquatic animal toxicity; and (Part *119* — for determination of units of measure and rates of penalty f hazardous substance discharge. It is immediately obvious that both t intent and the working structure of the regulations are highly dependent