Appendix A: The memorandum prepared by ENTRIX and presented in this appendix is a working review draft which was not edited or finalized by the Trustees.

Appendix A-5:

- **A-5**, "Risk to shorebirds and waterfowl from lead pellet ingestion at Skeet Hill in Castro Cove"

Original Author(s): ENTRIX

Distributed to the injury subcommittee in the cooperative NRDA process.

E N T R I X

MEMORANDUM

WORKING REVIEW DRAFT

ENTRIX, Inc.
2701 1st Avenue
Seattle, WA 98121
206/269-0104

Date: June 21, 2006

Re: Risk to shorebirds and waterfowl from lead pellet ingestion at Skeet Hill in Castro Cove

Project No. 3054545

PURPOSE

This memorandum estimates the potential risk to shorebirds and waterfowl from the ingestion of lead pellets within Castro Cove sediments from the former Skeet Hill shooting range.

APPROACH

A binomial model was applied to characterize lead shot risk to scaup and scoter, two representative diving duck species known to occur in moderate abundance within San Franscico Bay and/or Castro Cove (*see* URS 2002—Table 3-13). The model applied was consistent with that used to address lead shot risks to waterfowl in the Alameda Point Skeet Range (Battelle and ENTRIX 2002). Upon further examination, the Alameda model calculations were found consistent with those used previously to examine lead shot risks to shorebirds within Castro Cove (URS 2002). In the URS study the willet was modeled as the shorebird species for which maximum lead shot risk was assumed, based on biological and abundance characteristics. For the present analysis, the "average" or "most likely" (i.e., central tendancy,) and "reasonable maximum" (i.e., worst case) exposure scenarios were considered to estimate probabilistic risk for each bird guild.

The binomial approach assumes there is only one of two possible outcomes from an 'event'. In the present case, that 'event' is whether a bird encountering a pellet, consumes it as grit, or rejects the pellet as grit. The rate of acceptance/rejection is species specific, and dependent on a variety of biological and behavioral factors (e.g., probe depth, # probes/unit time). The probability of an initial encounter with a lead pellet (as a grit surrogate) is in turn dependent on a number of additional factors such as pellet density and depth, and the proportion of time a bird would use the site (i.e., the 'site use factor').

The previous ecological risk assessment (ERA) conducted for Skeet Hill evaluated the vertical and horizontal distribution of lead shot pellets to assess the probability of lead shot ingestion by shorebirds as opposed to waterfowl because the Skeet Hill mudflats of Castro Cove are dominated by shorebirds (URS 2002). The biological criterion derived for that assessment looked at impacts to the individual and extrapolated these probabilities outward to estimate a population level effect from estimates of the avian populations using Skeet Hill (*see* Table 3-14, URS 2002). Of the shorebird species present, the willet, long-billed curlew, and marbled godwit preferentially select grit the size of lead shot at Skeet Hill (i.e., Nos. 7 ½, 8, and 9). By intersection of species abundance and grit size preference, the willet was selected as the indicator species for the URS ERA as the species with the greatest exposure potential. (Compared to other shorebird species, their morphology--longer bill and larger body--was considered to further increase their probability of lead pellet ingestion at the site).

The previous URS ERA report did not address risks to waterfowl. In the present analysis, the risk assessment for waterfowl was considered with the approach used in the Alameda Point Skeet Range remedial investigation (Battelle and ENTRIX 2002). As indicated above, this binomial pellet ingestion model was the same as that used in the URS study (i.e., the differences that appear between the two formula simply relate to how they are written, not how they are calculated). Two waterfowl species – surf scoter and lesser scaup – were selected to represent the waterfowl present at Alameda Point, and the same species and biological input parameters used for these diving ducks were applied for Skeet Hill (e.g., home range, probes/day). These species have been used in other studies to examine metal contamination derived from estuarine dietary sources (Cohen et al. 2000). These waterfowl species (in particular the scaup) have also been documented in the bay area in high abundance, particularly in the winter months.

Based on the above description, the probability of a bird ingesting a given number of lead pellets in the risk assessment is predicted by:

$$P_r = {}_nC_r\, p^r (1\text{-}p)^{n\text{-}r}$$

Where:

$P(r)$ = probability of a bird ingesting r lead pellets in n probes for grit

r = number of lead shot pellets based on a No Observable Adverse Effect Level (NOAEL)

n = number of probes for grit a bird makes in a specified time period

${}_nC_r$ = number of possible combinations of n and r

p = probability that an individual bird will encounter a lead pellet in the range of 7 1/2 to 9 in a single probe

The risk that a given individual might pick up and retain a sufficient number of lead pellets to meet or exceed the relevant NOAEL is the probability of a bird ingesting a number of pellets ≥ NOAEL, or:

$$\text{Risk} = 1 - \sum(P_r;\ r < \text{NOAEL})$$

Where:

$$\sum(P_r; r < \text{NOAEL}) = (P_r; r = 0) + (P_r; r = 1) + \ldots + (P_r; r = \text{NOAEL-1})$$

A variety of lead shot No Observable Adverse Effects Level (NOAEL) values have been reported for waterfowl (mainly mallards). These values have ranged from one (Rattner et al. (1989) to six No. 4 shot (Sanderson 2002,; Korande et al. 1979). Meaning, in the studies cited, with the endpoints examined (e.g., growth), the range of the lowest 'dose(s)' of shot consumed that yielded *no* measurable effect was 1 to 6 shot, of the size Nno. 4 shot class. This shot size is typically used for hunting waterfowl, but is far larger than the shot size normally discharged at trap and skeet clubs. Shooters firing on clay targets at such clubs generally shoot shot sizes in the 7.5 to 9 range. At Skeet Hill, indeed all the shot recovered was in this smaller shot size range, and roughly 80% of the shot identified was of the No. 8 size. To compare the NOAEL values reported in the literature for No. 4 shot, requires a conversion to the size class of shot found at Skeet Hill in order for the results to have relevance. For this technical memo (and the Alameda study) this conversion was based on surface area equivalence; the range of the No. 4 lead shot NOAELs (i.e., 1 to 6) would equate to a range of 3 to 16 No. 8 shot.

Although the Alameda study used a NOAEL of 9 No. 8 shot, we have used a NOAEL of 3 No. 8 shot, and a LOAEL of 4 No. 8 shot, to be consistent with the previous modeling done on the willet from Castro Cove (URS 2002). Thus, the NOAEL applied can be considered to be significantly more conservative than that applied to Alameda.

To estimate the 'average' or 'central tendancy' waterfowl risk, the input parameters entered into the binomial model assumptions were based on the average estimates provided in the Alameda study or the literature cited therein. For the 'reasonable' maximum risk scenario, the appropriate maximum assumption provided in either the Skeet Hill (URS 2002) –or Almeda Point reports were used (URS 2002; Battelle and ENTRIX, Inc. 2002, respectively). These input assumptions are provided in the results Table 1

RESULTS

Risks based on the binomial probability calculations are shown in Table 1. For wading shorebirds (i.e., using the willet as the surrogate for all shorebirds) the probability that an individual bird exceeds the NOAEL based on typical exposure assumptions is **7.9E-06**; that is, less than 1 in 100,000 and more than 1 in 1,000,000 individuals. With reasonable maximum assumptions for all available input paramaters assumed, the probability increases to **1.6E-03**; that is, between 1 and 2 in 1,000 individuals. This increase of risk by roughly 200 times over the average exposure reflects compounded conservatism: the calculation is based on the assumption that the individual shorebird experiences the reasonable maximum for two parameters *simultaneously*.

For waterfowl, the probability that an individual exceeds the NOAEL based on typical exposure is **1.9 E-09**; that is, less than 1 in 100 million and more than 1 in a billion (i.e., essentially zero). With reasonable maximum assumptions for all available input parameters the probability increases to **4.1 E-5**; that is, less than 1 in 10,000 but more than 1 in 100,000 (or, specifically, 1 in 41,000). In other words, it would take roughly 41,000 scaup to visit the Skeet Hill site before a single individual would ingest enough lead to exceed the highly conservative NOAEL of 3 No. 8 shot.

CONCLUSION

Individual wading shorebirds *may* experience risks in excess of 1 in 1,000, but the typical shorebird incurs a risk of less than 1 in 100,000. The roughly 200-fold increase in risk with reasonable maximum assumptions indicates that a substantial amount of uncertainty exists around the upper bound estimate. However, the *average* shorebird risk (a measure much more applicable to non T&E populations with large number of individuals) is not significant.

Based on the input parameters detailed in Table 1, neither individual nor population level risks appear significant for waterfowl that may use the Skeet Hill area of Castro Cove. There appears to be no significant probability of exceeding the most conservative NOAEL for lead pellet consumption in Castro Cove. Additional dietary factors available in estuarine environments that are known to modulate lead and other metal toxicity in estuarine environments would appear to add a further element of certainty in this risk characterization (*see* Koranda et al. 1979; Cohen et al. 2000). That is, the risk may be substantially lower than that estimated from the above analysis because of factors inherent to estuarine diets of diving ducks.

Table 1. Risk calculations for lead pellet consumption by wading shorebirds and waterfowl at Skeet Hill in Castro Cove

		Central Tendency Assumptions			Conservative Assumptions	
Input Variable	**Units**	**Wading Bird[a]**	**Waterfowl[b]**		**Wading Bird**	**Waterfowl**
Shot count	#/ ft^2	688	688		688	688
Shot coverage	fraction	3.03E-02	3.03E-02	[c]	3.03E-02	3.03E-02
Preference	fraction	0.26	0.18	[d]	0.26	0.18
Pellet contact	fraction	0.5	0.5	[e]	1	1
p	fraction	3.94E-03	2.73E-03	[f]	7.88E-03	5.46E-03
Grit probe rate	#/day	1.5	152		3	290
Area Use Factor (AUF)	fraction	1	0.004	[g]	1	0.006
Grit retention period	days	21	11		21	20
N	count	32	7	[h]	63	35
NOAEL (= *r*)	count	3	3		3	3
Risk		**7.9E-06**	**1.9E-09**	[i]	**1.6E-03**	**4.1E-05**

Notes:

[a] Assumptions for shorebirds from URS (2002a)

[b] Assumptions for waterfowl from Battelle and ENTRIX (2002)

[c] Coverage based on pellet density and area, by pellet size (#7 1/2, #8, and #9)

[d] Preference for grit size > 2 mm, equivalent to #9 shot or larger

[e] Probability that a pellet, having been contacted, is ingested

[f] P = Shot coverage * Shot preference * Shot contact

[g] Skeet Hill = 10 ac = 0.04 km^2

AUF = Area(Skeet Hill) / Area(home range)

AUF (Scoter) = 10ac / 7km^2 = 0.006

AUF (Scaup) = 10ac / 20km^2 = 0.002

[h] N = Grit probe rate * AUF * Grit retention period

[i] Probability that a bird will equal or exceed the NOAEL for lead pellet consumption

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