BIG STONE GRANITE QUARRY HABITAT DEISGN: HSI RECLAMATION APPLICATION

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Abstract.--A West-central Minnesota granite quarry was studied to develop suitable post-mining land-use configurations. The quarry is adjacent to the federal Big Stone Wildlife Refuge. The primary post-mining land-use is projected to be wildlife habitat.

The study utilized recently developed Habitat Suitability Indexes (HSI) technology and other similar habitat models. This technology was incorporated into the reclamation process to generate design iterations and develop optimum design forms. With this technology, pre-mining conditions and post-mining alternatives can be numerically compared. The technology allows the targeting of cost effective and efficient habitat improvement. Plus it allows one to evaluate the effects of habitat improvements upon numerous species. In an economic manner, desired habitat improvements can guide mining operations, phasing, beautification, overburden placement, vegetation selection, wetland development and site amenities.

The HSI analysis indicated that the reclaimed quarry site could supplement existing refuge habitat conditions by adding several biophysical associations. The associations included a prairie grassland matrix, shrubland/woodland patches, wet meadow patches, open water matrix and emergent aquatic patches. Habitat scores were substantially improved ($p<.05$) for Great Egret (Egretta alba), Great Blue Heron (Ardea herodias), Western Grebe (Aechmophorus occidentalis), Wood Duck (Aix sponsa), White-tailed Deer (Odocoileus virginianus), Greater Prairie Chicken (Tympanuchus cupido americanus), Canvasback Duck (Aythya valisineria), Gadwall (Anas strepera) /Mallard (Anas platyrhynclos), Blue-winged Teal (Anas discors) Green-winged Teal (Anas crecca) Northern Shoveler (Anas clypeata) complex.

INTRODUCTION

The Big Stone quarry, operated by the Ortonville Stone Company is located approximately two miles southeast of Ortonville, Minnesota along State Highway 75 (Figure 1). The operation produces crushed stone for use as railroad ballast and construction aggregate.

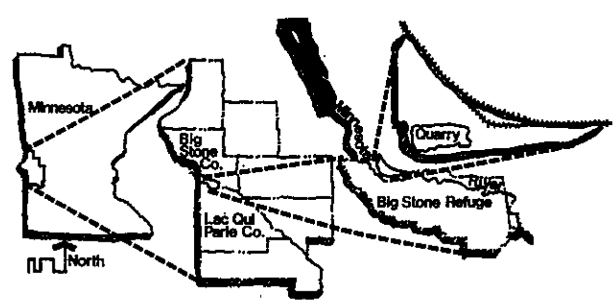

Figure 1. This series of maps illustrate the location of the granite quarry.

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Although mining operations at this mine will conceivably continue for over 80 years, granite quarrying is only a transitional land-use. The post-mining land-use should be carefully considered and developed in conjunction with the earth moving activities of the quarry operator; otherwise, the configuration of the post-mine landscape may be inappropriate with the intended post-mining land-use.

Burley and Thomsen (198-) have described the diversity of landform configurations associated with various post-mining land-uses. They illustrated the differences between these landforms. Optimum landforms for housing can be quite different from optimum landforms for wildlife.

At the Big Stone Quarry, the post-mining land-use with the highest potential for successful development is wildlife habitat. The quarry is adjacent to the Big Stone Refuge, operated by the United State Fish and Wildlife Service (FWS). According to the refuge's recent masterplan (FWS 1986), additional aquatic habitat, upland habitat and cavity nesting habitat is desired to complement the existing wildlife features within the refuge.

Opportunities for other post-mining land-uses are not as promising. Housing and industrial land-uses are not in demand for the area. In addition, the post-mining landscape potential for farmland is low. Shallow soils and the creation of a lake make agronomic farming impractical. Therefore, developing the landscape for wildlife is the most promising post-mining land-use.

Burley and Thomsen (198-) indicate that post-mining landscapes for wildlife are very species specific. A generic lake intended for fish is not adequate. The lake must have identifiable features and specific landscape patterns that match the habitat needs for the desired wildlife. The landscape created for pan-fish will be quite different from a lake intended for trout.

Habitat models are tools that can assist in developing a specific landscape prescription to meet the habitat requirements for desired wildlife.

Intent of Paper

This paper illustrates the application of habitat models to produce wildlife habitat post-mining land-use plans at the quarry. Many biologists, landscape architects and planners are still unfamiliar with these models and are unfamiliar with the potential these models possess in reclamation applications. It is important that reclamation specialists become acquainted with the significance and utility of these habitat models.

Habitat Models and Wildlife

The rapidly changing technology available to commercial and industrial interests today has created the need for a system in which landscape architects, ecologists and wildlife biologists can study the effects of proposed land management decisions upon wildlife habitat. Within the last ten years, species specific habitat models have been developed by the FWS, the U.S. Army Corps of Engineers and by several independent researchers. These models are equations which attempt to predict the suitability of a particular landscape pattern for a specific wildlife group or species. Verner, et al., (1986) recently edited Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. For individuals not familiar with wildlife models, this book is a good introduction to technical issues concerning habitat modeling. Burley (1983) illustrated an early use of habitat models for reclamation applications.

The models do have limitations. Many of the models are expert guesses concerning wildlife habitat requirements. Some of these models have been tested and require further refinement. Some models are based upon multiple regression techniques and have a potentially greater reliability. The models must be applied within the naturally occuring range for the selected species. The habitat scores obtained from the models are not exact population predictions but rather habitat scores indicating the relative suitability of the habitat to sustain a particular species. Despite these limitations, the models represent current knowledge and understanding about wildlife habitat needs and are useful tools to develop landscapes for wildlife.

Description of Study Area

The granite quarry is an exposed portion of the precambrian shield. The precambrian rocks became exposed by the Glacial River Warren. The post-glacial Minnesota River now occupies the valley created by the Glacial River Warren. The quarry is adjacent to the Minnesota River. Because the precambrian rocks are relatively impervious to water, the Minnesota River is the termination of groundwater flow from the Big Stone Lake Watershed (Cotter , et al., 1966) and the Pomme de Terre River Watershed (Cotter and Bidwell (1966).

Soils are shallow stony loams with numerous rock outcrops. This soil supports xeric prairie, lichen colonies and ball cactus (Mammilaria vivipera). In addition, wet forest (defined by Curtis 1959) occupy the land along the Minnesota River.

The quarry's mining operations contain several phases. First, surficial unconsolidated material is removed and stockpiled. Once the granite has been exposed, vertical holes are drilled using a rotary drill. The holes are filled with an explosive slurry. The active ingredient is ammonium nitrate. The explosive slurry is detonated and the granite is fractured into large boulders. A dipper shovel loads the granite boulders into trucks. The trucks haul the boulders to the primary rock crusher. From the primary rock crusher, the rock is moved by conveyor to a secondary rock crusher. The rock is then screened and sorted to produce crushed granite ranging in size from 2 inches to 1-3/4 inches in diameter. About 15 to 20 percent of the screened material remains as unmarketable fines. The marketable product is loaded into rail hopper cars ready for shipment. Unmarketable material can be utilized in reclamation operations. The granite will be extracted to a depth approximately 90 feet or more below the water table. This means that once the operations are complete, a large lake will occupy the quarry site. The volume of the unmarketable fines will not be of sufficient size to completely fill in the lake.

Reclamation planning and habitat modeling should determine the optimum landscape patterns for placement of unmarketable material in conjunction with the newly created lake.

METHODOLOGY

Figure 2 outlines the process employed to develop the post-mining land-use plan. Nine wildlife groups/species were selected for specific habitat improvement. Table 1 lists the groups/species studied and the modelling procedures employed.

Two types of habitat models were selected for use in the study. The first set were recent FWS models, Habitat Evaluation Procedures (HEP). A microcomputer version (Hays and Heasley 1986 and HEP Software support HEP Group (1985) assisted in the modelling effort. The key component of HEP is the Habitat Suitability Index (HSI). By rating the sites with HSI graphs and equations, proposed changes can be evaluated in a relatively objective and predicable manner. HSI procedures were the primary basis for most of the models utilized in this study. The other set of models were developed by Flood, et al., (1977), and are older FWS models.

The HEP models were transcribed into a format resembling the format presented by Flood (1977). In addition, some models were modified slightly with the removal or addition of habitat features. A copy of these equations and their format can be obtained by writing the authors of this paper.

Three primary habitat treatments were studied. The first treatment was the 1986 existing site conditions. The second treatment was the post-mining condition. This condition would occur in approximately 2056 A.D. This treatment examines the hypothetical situation where no wildlife planning would occur. Under this condition, the mining operation would complete its extraction in 2056 and abandon the quarry. This second alternative is an important alternative to examine. Burley and Hopkins (1984) indicated that some abandoned mine configurations can be highly suitable to some wildlife populations. Therefore, there is the possibility that the abandoned post-mining landscape could be intrinsically suitable for the selected wildlife species without any or few modifications. The third treatment was the 2056 post-mining situation where the landscape was carefully reclaimed for the nine wildlife groups/species.

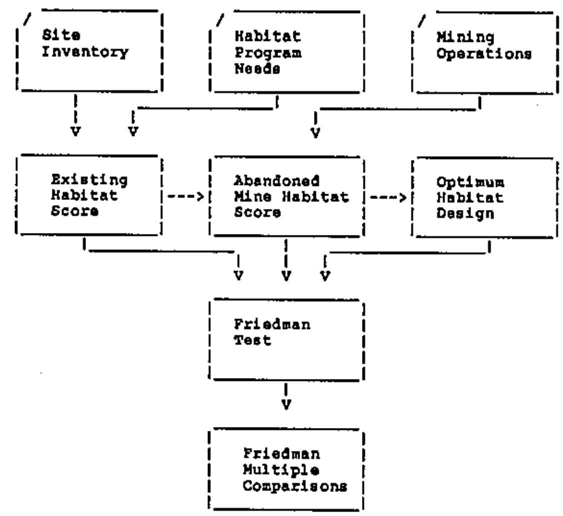

Figure 2. Flowchart of Habitat Design and Evaluation Process

Table 1. List of Species/Groups and Habitat Methods Employed.

WILDLIFE SPECIES/ GROUP	HABITAT EVALUATION METHOD
Great Blue Heron (*Ardea herodias*)	HEP/HSI (Short and Cooper 1985)
Great Egret (*Egretta alba*)	HEP/HSI (Chapman and Howard 1984)
Western Grebe (*Aechmophorus occidentalis*)	HEP/HSI (HEP Software Support Group 1985 and Hays and Heasley 1986)
Wood Duck (*Aix sponsa*)	HEP/HSI (Sousa and Farmer 1983)
American Coot (*Fulica americana*)	HEP/HSI (Allen 1985)
White-tailed Deer (*Odocoileus virginianus*)	Pre-HEP (Flood et al., 1977)
Greater Prairie Chicken (*Tympanuchus cupido americana*)	HEP/HSI (Prose 1985)
Canvasback (*Aythya valisineria*)	HEP/HSI (HEP Software Support Group 1985 and Hays and Heasley 1986)
Gadwall (*Anas strepera*), Mallard (*Anas platyrhynclos*), Blue-winged Teal (*Anas discors*), Green-winged Teal (*Anas crecca*), Northern Shoveler (*Anas clypeata*)	HEP/HSI (Sousa 1985, Flood et al., 1977, HEP Software Support Group 1985 and Hays and Heasley 1986)

Friedman two-way analysis of variance by ranks and the Friedman multiple comparison procedure were nonparametric statistical methods employed to compare landscape treatments across groups/species (blocks). These statistical methods are illustrated by Daniel (1978). Nonparametric methods were selected because the data set could not satisfy the assumptions associated with parametric methods. The Friedman two-way analysis of variance by ranks is a distribution free test with few restrictions.

RESULTS

Table 2 lists the results of the habitat scores for the existing condition. Table 3 list the results of the habitat scores for the abandoned quarry situation. Table 4 lists the results of the habitat scores for the planned habitat situation.

The Friedman two-way analysis of variance by ranks (Table 5) revealed at least one habitat treatment was collectively better than the other treatments scores ($p<0.5$). The Friedman multiple comparisons procedure indicates that the planned habitat treatment yielded higher results. There was not enough statistical evidence to conclude that the existing situation and abandonment situation yielded different results.

Table 2. Habitat Scores for Existing Conditions

WILDLIFE SPECIES/ GROUP	HABITAT ACRES	HABITAT SCORE	TOTAL HABITAT SCORE
Great Blue Heron	2.10	0.11	0.230
Great Egret	4.00	0.21	0.840
Western Grebe	6.00	0.28	1.670
Wood Duck	2.10	0.25	0.525
American Coot	2.10	0.66	1.380
White-tailed Deer	12.00		4.680
Greater Prairie Chicken	136.10	0.30	40.830
Canvasback	2.10	0.00	0.000
Gadwall, Mallard, Blue/Green-winged Teal Northern Shoveler	2.10	0.17	0.357
		GRAND TOTAL HABITAT SCORE	50.51

Table 3. Habitat Scores for Abandonded Contition

WILDLIFE SPECIES/ GROUP	HABITAT ACRES	HABITAT SCORE	TOTAL HABITAT SCORE
Great Blue Heron	113.20	0.16	18.112
Great Egret	15.00	0.23	3.450
Western Grebe	15.00	0.08	1.200
Wood Duck	113.20	0.00	0.000
American Coot	113.20	0.41	46.412
White-tailed Deer	59.60	0.55	32.780
Greater Prairie Chicken	99.80	0.40	39.920
Canvasback	113.20	0.20	22.640
Gadwall, Mallard, Blue/Green-winged Teal Northern Shoveler	113.20	0.25	28.300
		GRAND TOTAL HABITAT SCORE	192.81

Table 4. Habitat Scores for Optimum Habitat Condition

WILDLIFE SPECIES/ GROUP	HABITAT ACRES	HABITAT SCORE	TOTAL HABITAT SCORE
Great Blue Heron	113.20	0.87	98.031
Great Egret	15.00	0.69	10.320
Western Grebe	15.00	0.78	11.745
Wood Duck	113.20	0.93	105.270
American Coot	113.20	0.99	111.610
White-tailed Deer	59.60	0.96	57.394
Greater Prairie Chicken	99.80	1.00	99.800
Canvasback	113.20	0.60	67.920
Gadwall, Mallard, Blue/Green-winged Teal Northern Shoveler	113.20	0.96	108.670
		GRAND TOTAL HABITAT SCORE	670.76

Table 5. Friedman Two-way Analysis of Variance Test and Friedman Multiple Comparisons Test

WILDLIFE SPECIES/ GROUP	EXISTING SITE	RANK	ABANDONED SITE	RANK	POST-DESIGN	RANK
Great Blue Heron	0.230	3.00	18.112	2.00	98.031	1.00
Great Egret	0.840	3.00	3.450	2.00	10.320	1.00
Western Grebe	1.670	2.00	1.200	3.00	11.745	1.00
Wood Duck	0.525	2.00	0.000	3.00	105.270	1.00
American Coot	1.380	3.00	46.412	2.00	111.610	1.00
White-tailed Deer	4.680	3.00	32.780	2.00	57.394	1.00
Greater Prairie Chicken	40.830	2.00	39.920	3.00	99.80	1.00
Canvasback	0.000	3.00	22.640	2.00	67.920	1.00
Gadwall, Mallard, Blue/Green-winged Teal, Northern Shoveler	0.357	3.00	28.30	2.00	108.670	1.00
	50.51	24.00	192.81	21.00	670.76	9.00

199.70 MINUS 135.00 = 64.70

If T> or = 9.46 (Z-stat), then there is enough evidence to support thet the scores are different at p< or = to 0.05.

TEST STATISTICS		COMPARISON RESULTS	
|EX-POST| =	15.00	EXISTING	---
|EX-ABAN| =	3.00	ABANDONED	---
|POST-ABAN| =	12.00	POST	---

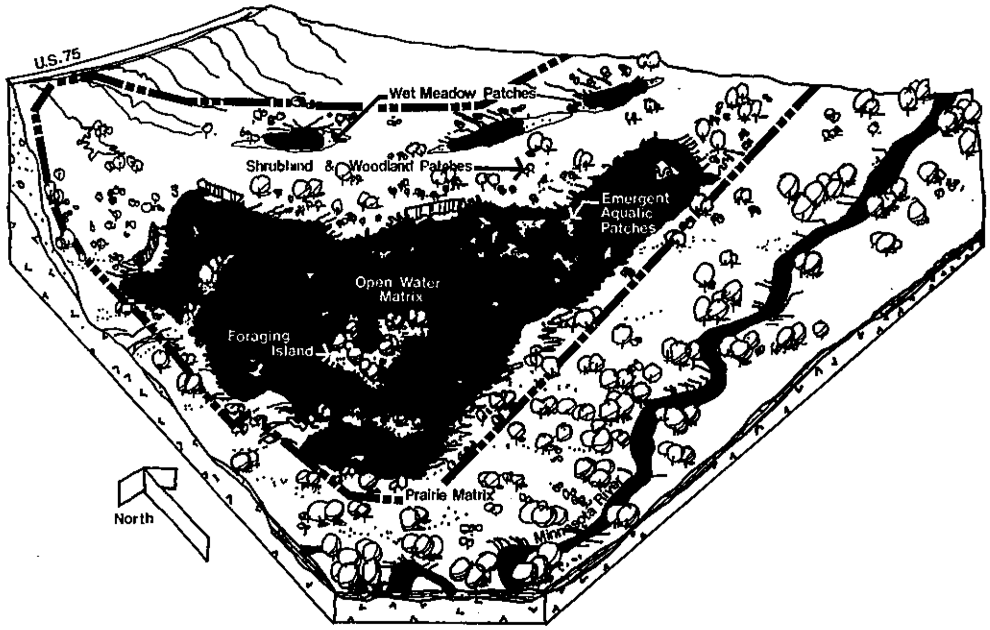

Figure 3. This drawing illustrates landscape patterns of a proposed post-mining land-use plan.

DISCUSSION

Figure 3 is a map illustrating the landscape patterns of the planned habitat treatment. The landscape includes a prairie grassland matrix, shrubland/woodland patches, wet meadow patches, open water matrix and emergent aquatic patches. Forman and Godron (1986) describe the landscape ecological terminology for defining matrixes and patches. This landscape pattern is considered to be an optimum configuration to meet the programing needs associated with the selected wildlife species/groups.

The open water matrix is a lake created by the mining operations. Under the abandonment treatment, the lake would be a large and deep open body of water suitable for only trout. This type of landscape would not be suitable for the waterfowl and shorebirds programed for the site. However, by adding emergent aquatic patches and patches of upland features in the waterbody, the open water matrix becomes suitable for programed species.

To create the suitable open water matrix, blocks of the quarried granite must remain intact. The blocks must be of sufficient height to rise above or near the surface of the waterbody. Leaving these blocks intact will reduce the volume of marketable crushed stone delivered from the quarry. The quarry operator may need to be monetarily compensated to leave this resource intact.

Within these islands, grassland and shrubland/woodland patches will create nesting habitat for American Coot, Mallard, Gadwall, Pintail, Green-winged Teal, Blue-winged Teal, Northern Shoveler, Wood Duck, Great Egret and Great Blue Heron. Emergent aquatic patches will provide foraging and rearing opportunities for these birds.

Beyond the open waterbody matrix, a grassland matrix with wet meadow patches and shrubland/woodland patches provide further foraging opportunities for selected waterfowl plus habitat for the Greater Prairie Chicken and for White-tailed Deer.

CONCLUSION

Habitat modeling allows the wildlife biologist, landscape architect and reclamationist the opportunity to study and compare various post-mining landscape treatments for a wide variety of wildlife habitats. The models create a very specific habitat program to develop a landscape. In the future, these models may become extensively incorporated into developing post-mining landscapes for wildlife.

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