U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

SACRAMENTO RIVER WHITE STURGEON SPAWNING CRITERIA

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PREFACE

The following is the final report for the U.S. Fish and Wildlife Service's delphi analysis to develop spawning criteria for Sacramento River white sturgeon, part of the Anadromous Doubling Plan Instream Flow Investigations, a 5-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations is to provide reliable scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this report are welcomed. Written comments or information can be submitted to:

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I. INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter and spring runs), steelhead, and white and green sturgeon. The Central Valley Project Improvement Act Anadromous Doubling Plan calls for February through May Sacramento River flows at Grimes of 17,700 cfs (in wet and above normal water years) for white and green sturgeon spawning.

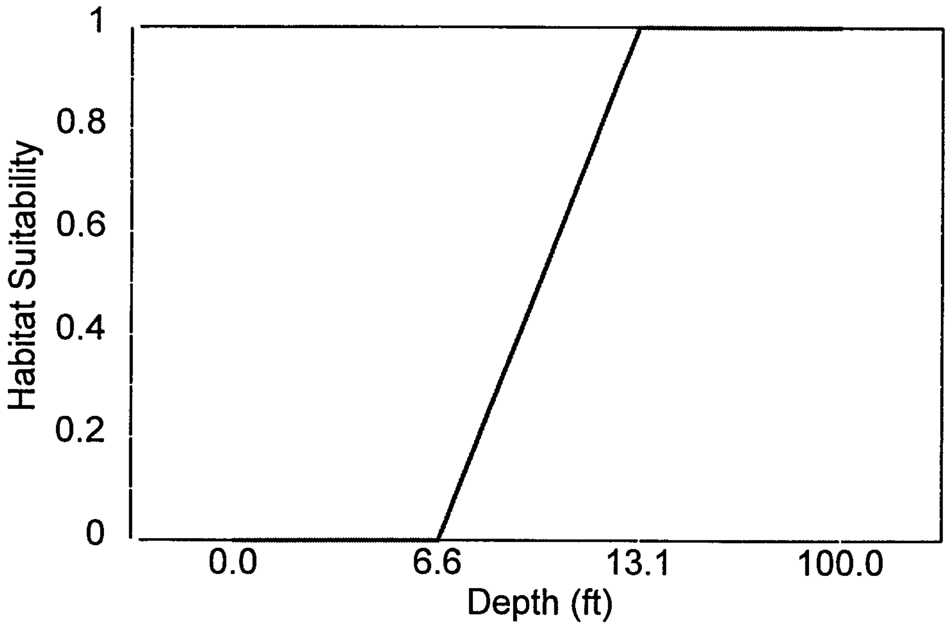
The Physical Habitat Simulation System (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM) is a hydraulic and habitat model that can be used to predict physical habitat availability over a range of streamflows for various fish species and other instream activities. In this case, PHABSIM could be used to determine the relationship between Sacramento River flows and the amount of physical habitat available for white sturgeon spawning. The resulting relationship could be used to validate the above Doubling Plan flow, or to derive different recommendations for Sacramento River flows for white sturgeon spawning.

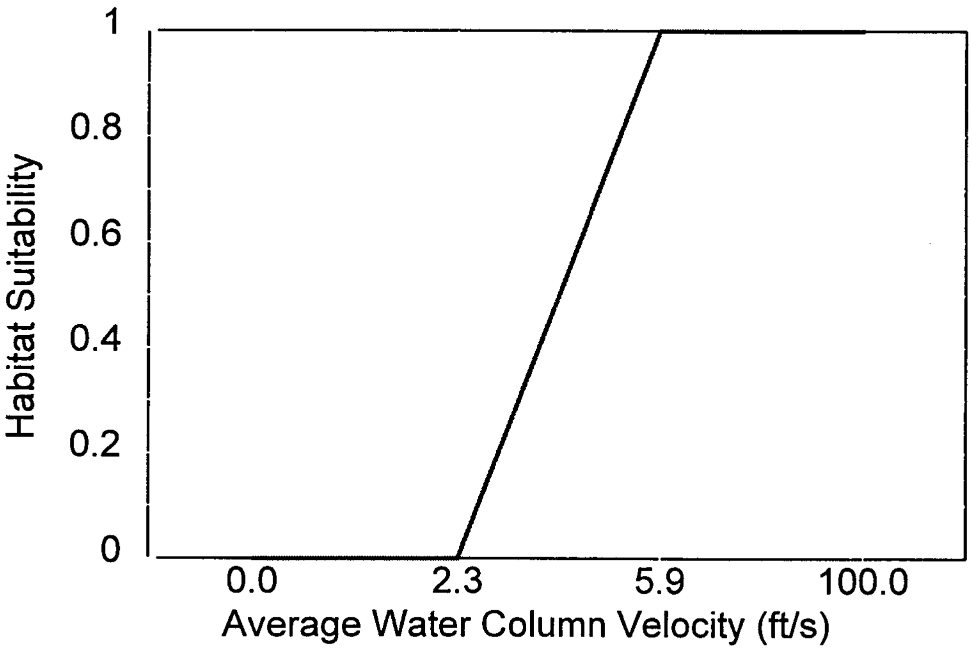
Habitat suitability criteria (HSC or SI curves) are used within PHABSIM to translate hydraulic and structural elements of rivers into indices of habitat quality (Bovee 1986). Suitability index values range from zero to one. HSC (Table 1, Figure 1) have been developed for white sturgeon spawning in the Lower Columbia River by sampling for white sturgeon eggs with spawning mats (Parsley and Beckman 1994). However, these criteria might not be transferrable to the Sacramento River because Lower Columbia River flows are more than an order of magnitude greater than Sacramento River flows, and because the Lower Columbia River criteria were developed in tailrace areas, in contrast to the areas in which criteria would likely be applied on the Sacramento River, at least 100 miles downstream of Keswick Reservoir. In addition, the

Table 1
Lower Columbia River Substrate Suitability Criteria (from Parsley and Beckman 1994)

Substrate Type	Suitability
Sand	0
Gravel	0.5
Cobble	1
Boulder	1
Bedrock	1

Figure 1
Lower Columbia River White Sturgeon Spawning Habitat Suitability Curves
(from Parsley and Beckman 1994)





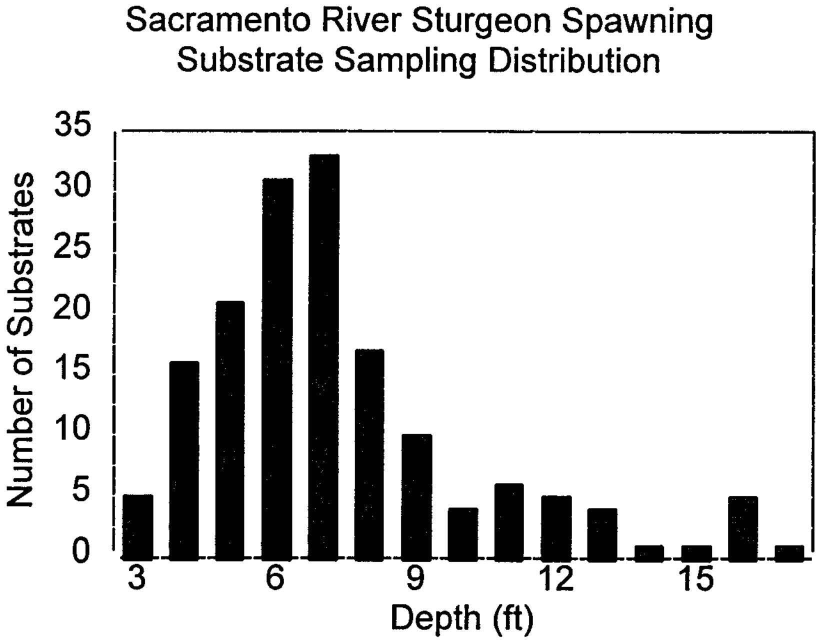
Lower Columbia River criteria do not have an upper limit for either depth or velocity. There could be an upper limit on velocity for sturgeon spawning because of either physiological (i.e., swimming speed limitations) or behavioral (i.e., to prevent eggs from being carried into areas with unsuitable substrates) factors. Sustained swimming speeds of various sturgeon species range from 0.2 to 4.5 body lengths per second (Beamish 1978).

Schaffter (1994) deployed artificial substrate egg samplers of latex-coated animal hair at various locations in the Sacramento River in 1992. White sturgeon eggs were captured six times on the egg samplers (Table 2). The microhabitat characteristics of the locations where eggs were captured (Table 2) fell within the range of depths, velocities and substrate types of all of the artificial substrate egg sampling locations (Table 3, Figure 2). Larger substrate types (cobble and larger) were not sampled in 1992 (Schaffter, personal communication). The velocities in Table 2 and Figure 2 are average water column velocities, estimated using Schaffter's (1994) measurements of velocity (30 cm off of the bottom), the water depth, and the 1/mth power law equation (Milhous et al 1989).

Table 2
Characteristics of Spawning Mat Locations Where White Sturgeon Eggs Were Collected
Data adapted from Schaffter (1994)

Number of eggs collected	Water Depth (ft)	Average Water Column Velocity (ft/s)	Substrate
1	5	4.67	50% gravel, 50% cobble
1	8	5.81	gravel
2	6.7	4.68	gravel
5	6.3	4.51	gravel
7	5.8	4.76	gravel
19	13	5.17	gravel

Figure 2
Data Adapted from Schaffter (1994)



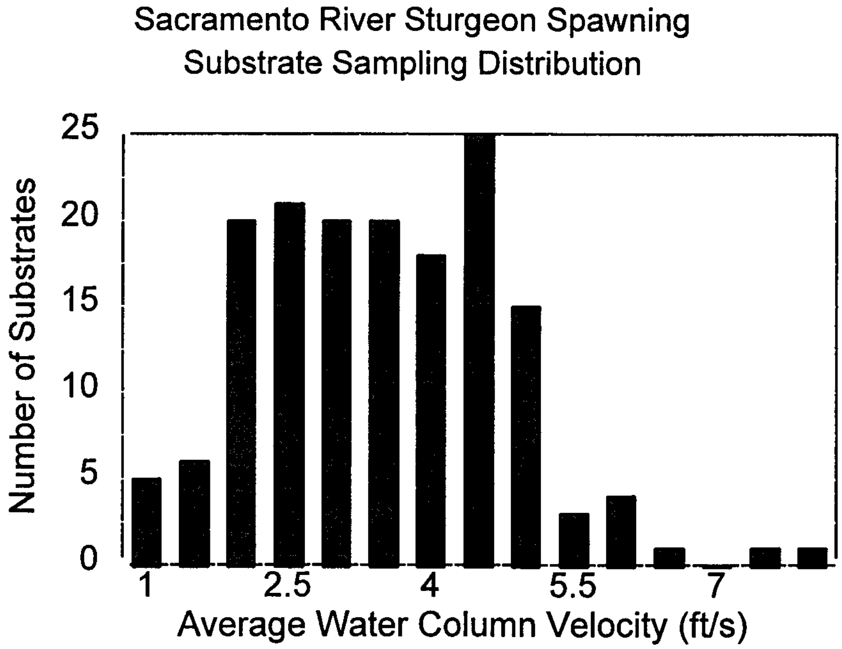


Table 3
Sacramento River Sturgeon Spawning Substrate Sampling Distribution
(data from Schaffter 1994)

Substrate Type	Frequency of Substrates Sampled
Sand	29
80% sand, 20% gravel	8
50% sand, 50% gravel	22
10% sand, 90% gravel	1
gravel	91
50% gravel, 50% cobble	9

II. METHODS

Since there were not sufficient data available to develop site-specific criteria for white sturgeon spawning in the Sacramento River (Category II criteria), it was decided that Category I criteria should be developed for white sturgeon spawning in the Sacramento River using a delphi analysis. A delphi analysis (Bovee 1986) is an iterative process where a group of experts are polled, with controlled feedback provided, the goal being a consensus among the group. Seven experts were identified who had experience using sampling mats to collect microhabitat use data for white sturgeon spawning: 1) Mike Parsley, Columbia River Research Laboratory, NBS; 2) Ray Schaffter, CDFG Stockton; 3) George McCabe, NMFS; 4) Jim Chandler, Idaho Power Company; 5) Paul Anders, Kootenai Tribe of Idaho; 6) Larry Hildebrand, RL&L Environmental Services LTD; and 7) Vaughn Paragamian, Idaho Department of Fish and Game. All of these experts agreed to participate in the delphi analysis.

In the first round of the delphi analysis, the participants were sent an information request, presenting the above information, and asking them to fill in three tables. These tables were refined slightly during the analysis to make the questions more clear and (based on the suggestion of one participant) add an additional substrate category. The appendix of this report is the final version of the three tables. In the subsequent three rounds, the participants were given the opportunity to revise their earlier responses based on a summary of the group's responses (specifically, the median and first and third quartile responses to each question). Respondents were asked to explain the basis for their response if it was less than the first quartile or greater than the third quartile of the group's responses to the previous round. The participants were also invited to provide any additional information or to write any comments, ideas or logic that they used in their answers. All such information was summarized and presented to the participants in the next round. All responses were kept anonymous. The delphi analysis was ended after the fourth round based on a qualitative evaluation of the stability of individual's responses and a quantitative measure of the degree of convergence (for depth and velocity responses). Specifically, the quantitative measure was the average (for all depth and velocity questions) of the coefficient of variation (the standard deviation divided by the mean) of the responses for each question. The median values in the last round were used as the final Category I criteria. In the last round, the respondents were also polled on the degree to which various factors influenced their responses.

III. RESULTS/DISCUSSION/CONCLUSIONS

The final Category I Sacramento River white sturgeon spawning criteria, which, as noted above, were the median responses for the last round of the delphi analysis, are given in Tables 4 and 5 and Figure 3. The quantitative measure of the degree of convergence of depth and velocity reponses had values of 0.56, 0.21, 0.10 and 0.09 for the four rounds, demonstrating that there was a movement towards consensus during the delphi analysis, and that convergence changed little between the third and fourth rounds. The latter conclusion is consistent with a qualitative evaluation that individuals' responses changed very little between the third and fourth rounds. With the exception of one individual, there was complete consensus on all of the substrate SI values by the last round, except for the SI value for snags. Even for this substrate category, excluding the above individual, the range of responses was from 0.3 to 0.4. Accordingly, we conclude that there was success in reaching consensus.

Based on the questions posed to the respondents in the last round of the delphi analysis, the SI curves developed for the Lower Columbia River (Parsley and Beckman 1994) and data from other rivers (with mean values of the responses for these, respectively, of 3.7 and 3.8, on a scale of 1 to 5) had more influence on their responses than data from the Sacramento River or responses of the other delphi analysis participants (mean values, respectively, of 2.8 and 2.2). The final Category I criteria are generally consistent with the data in Table 2; specifically: 1) all of the velocity values in Table 2 have SI values greater than 0.5, and two have SI values of 1.0; 2) three of the depth values in Table 2 have SI values between 0.5 and 1.0, and one has an SI value of 1.0; and 3) the substrate values in Table 2 have SI values of at least 0.5. The only slight inconsistency is that one of the depth values in Table 2 (5 feet) has an SI value of 0, but this is highest depth that has an SI value of 0. The consistency of the substrate data in Table 2 with the substrate SI values is difficult to completely evaluate, given that no substrates with SI values of 1.0 were sampled by Schaffter (1994).

Given that there are some differences between the Category I Sacramento River white sturgeon spawning criteria and the Category II Lower Columbia River white sturgeon spawning criteria (Parsley and Beckman 1994), it would be useful to collect at least enough additional spawning mat data from the Sacramento River to conduct a transferability test (Thomas and Bovee

1993), to see which, if either, of the two above criteria are transferable to the Sacramento River. Ideally, given sufficient resources, enough additional spawning mat data could be collected from the Sacramento River to develop Category II Sacramento River white sturgeon spawning criteria. At the very least, the Category I Sacramento River white sturgeon spawning criteria can be used with habitat availability data to assess, using PHABSIM, the relationship between Sacramento River flows and weighted useable area for white sturgeon spawning. Since the Category I criteria suggest that white sturgeon are limited to spawning in deep, fast areas with large substrates, transects for simulating available habitat should be selected in these types of areas.

Table 4
Sacramento River White Sturgeon Spawning Criteria for Velocity & Depth

Velocity (ft/s)	SI Value	Depth (ft)	SI Value
0	0	0	0
2.3	0	5	0
3.9	0.5	6	0.5
5	1	10	1
12.5	1	100	1
19.95	0.5		
25.5	0		
100	0		

Table 5
Sacramento River White Sturgeon Spawning Criteria for Substrate

Substrate Type	Substrate Particle Size	Suitability Index
snags	---	0.35
other plant detritus	---	0
compacted clay	---	0
silt/fine clay	< 0.02"	0
sand	0.02 - 0.1"	0
gravel	0.1 - 2.5"	0.5
cobble	2.5 - 10"	1
boulder	10" - 12'	1
bedrock	>12'	1

IV. REFERENCES

Bovee, K. D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream Flow Incremental Methodology. Instream Flow Information Paper No. 21. U.S. Fish and Wildlife Service Biological Report 86(7). 235 pp.

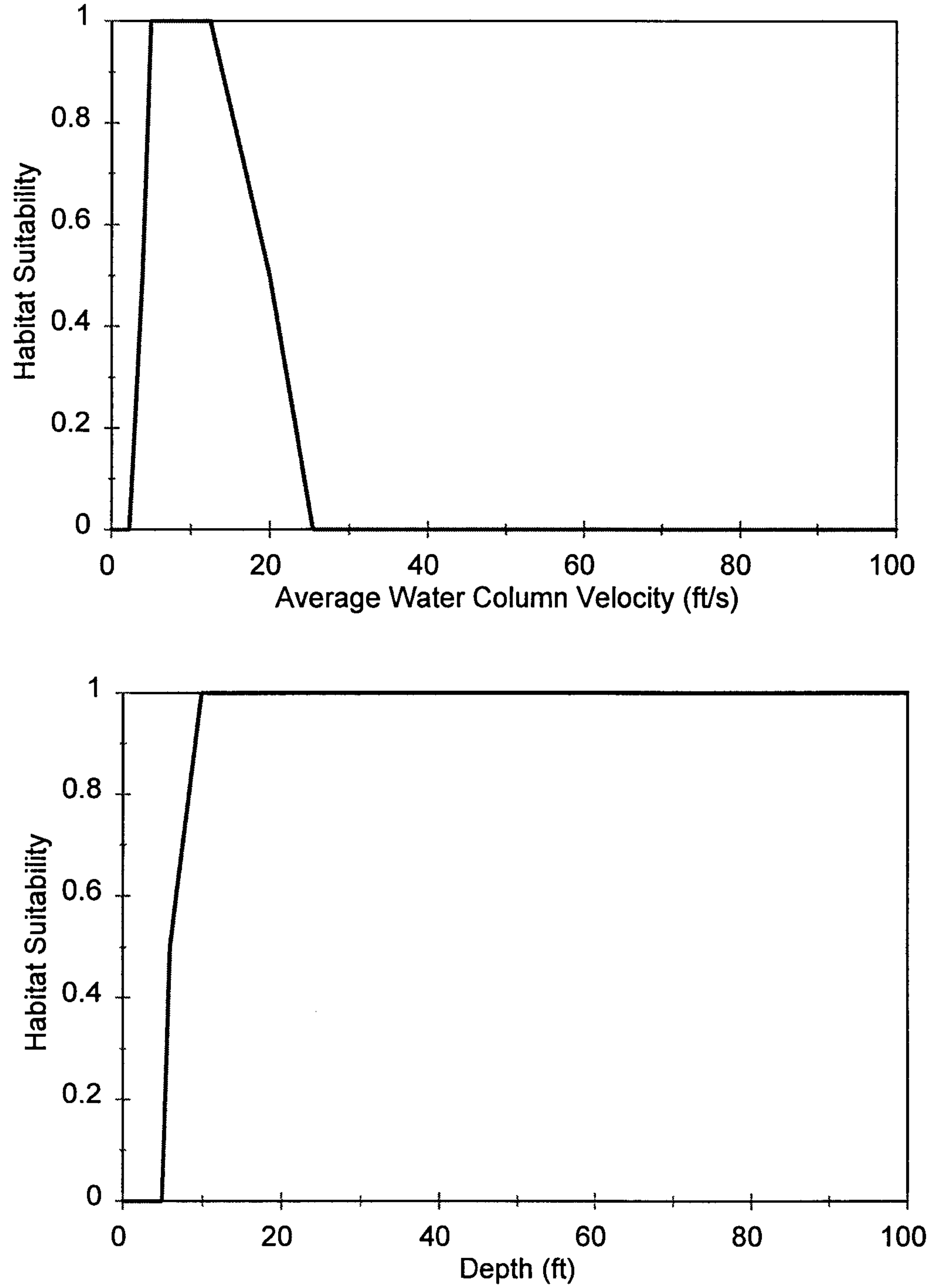
Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Physical Habitat Simulation System Reference Manual - Version II. Instream Flow Information Paper No. 26. Biological Report 89(16). National Ecology Research Center, Fish and Wildlife Service.

Parsley, M.J. and L.G. Beckman. 1994. White sturgeon spawning and rearing habitat in the Lower Columbia River. North American Journal of Fisheries Management 14:812-827.

Schaffter, R.G. 1994. Some aspects of white sturgeon spawning migrations and spawning habitat in the Sacramento River, California. Draft report, California Department of Fish and Game.

Thomas, J.A. and K.D. Bovee. 1993. Application and testing of a procedure to evaluate transferability of habitat suitability criteria. Regulated Rivers: Research and Management 8:285-294.

Figure 3
Sacramento River White Sturgeon Spawning Habitat Suitability Curves



APPENDIX
INFORMATION REQUEST TABLES

Velocity Condition	Average Water Column Velocity (ft/s)
Lowest velocity considered to be optimal	
Highest velocity considered to be optimal	
Level velocity must decrease to for Suitability Index = 0 (use N if never occurs)	
Level velocity must increase to for Suitability Index = 0 (use N if never occurs)	
Level velocity must decrease to for Suitability Index = 0.5 (use N if never occurs)	
Level velocity must increase to for Suitability Index = 0.5 (use N if never occurs)	

Depth Condition	Total Water Column Depth (feet)
Lowest depth considered to be optimal	
Highest depth considered to be optimal	
Level depth must decrease to for Suitability Index = 0 (use N if never occurs)	
Level depth must increase to for Suitability Index = 0 (use N if never occurs)	
Level depth must decrease to for Suitability Index = 0.5 (use N if never occurs)	
Level depth must increase to for Suitability Index = 0.5 (use N if never occurs)	

Substrate Type	Substrate Particle Size	Suitability Index
snags	---	
other plant detritus	---	
compacted clay	---	
silt/fine clay	< 0.02"	
sand	0.02 - 0.1"	
gravel	0.1 - 2.5"	
cobble	2.5 - 10"	
boulder	10" - 12'	
bedrock	>12'	