BACK TO THE FUTURE? REVISTING AN INNOVATIVE DOWNSTREAM FISH PASSAGE SYSTEM

Rich Piaskowski
Portland District, USACE
Richard.m.piaskowski@usace.army.mil
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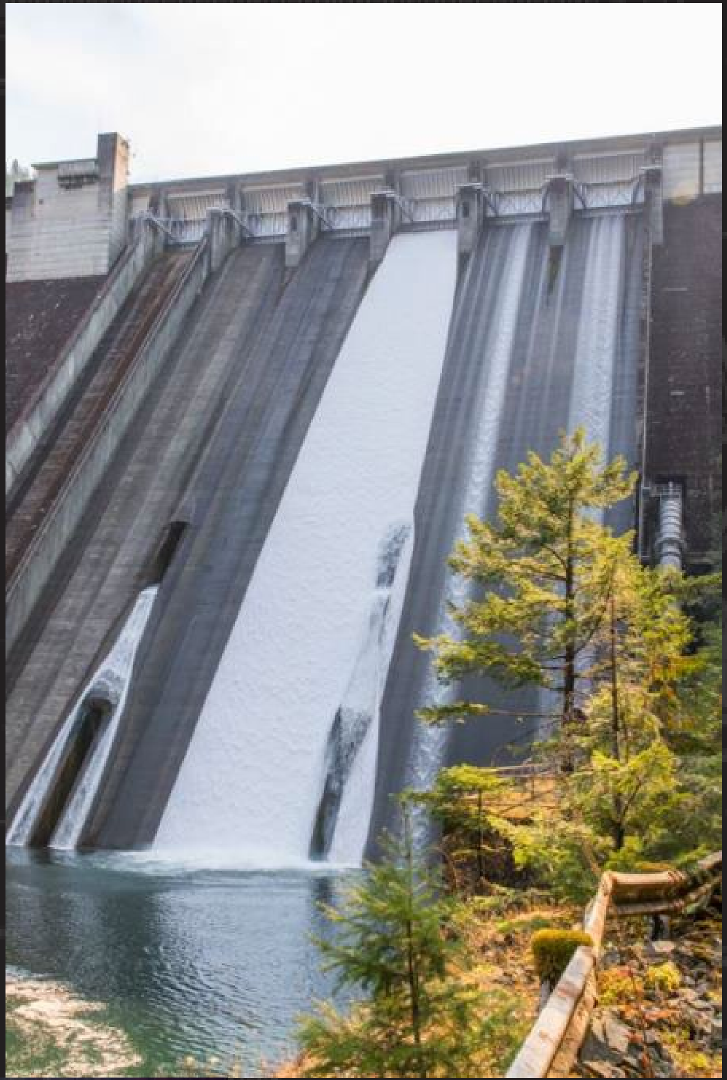

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Surface collection at PNW high-head dams has been a focus for improving downstream fish passage.

The number of working examples is small, with variable operating conditions, limiting the ability to assess what factors drive performance.

There are three working examples of surface collectors for Chinook at high head dams (hydraulic head >30 m)

- Swift Dam
- North Fork Dam
- Round Butte Dam

SWIFT Surface Collector

Photo Source: Cramer Fish Sciences (2015)

Round Butte Surface Collector

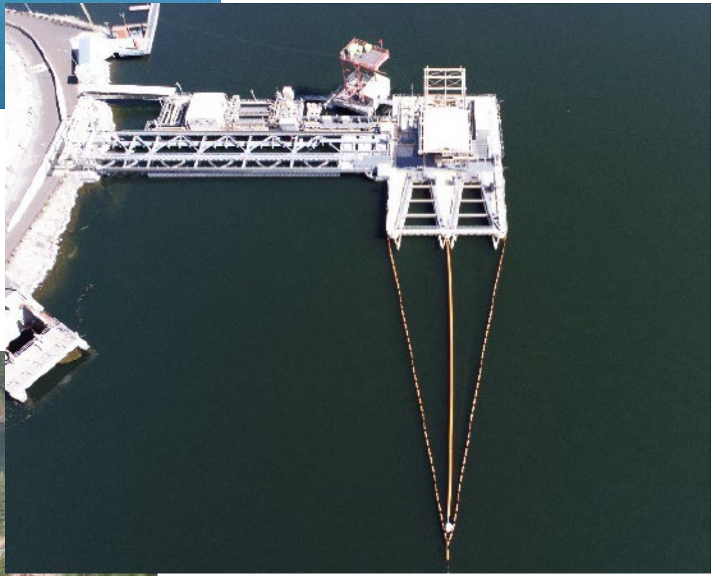

Photo Source: Stillwater Sciences (2022)

North Fork Surface Collector

Photo Source: Ackerman (2023)

GREEN PETER DAM

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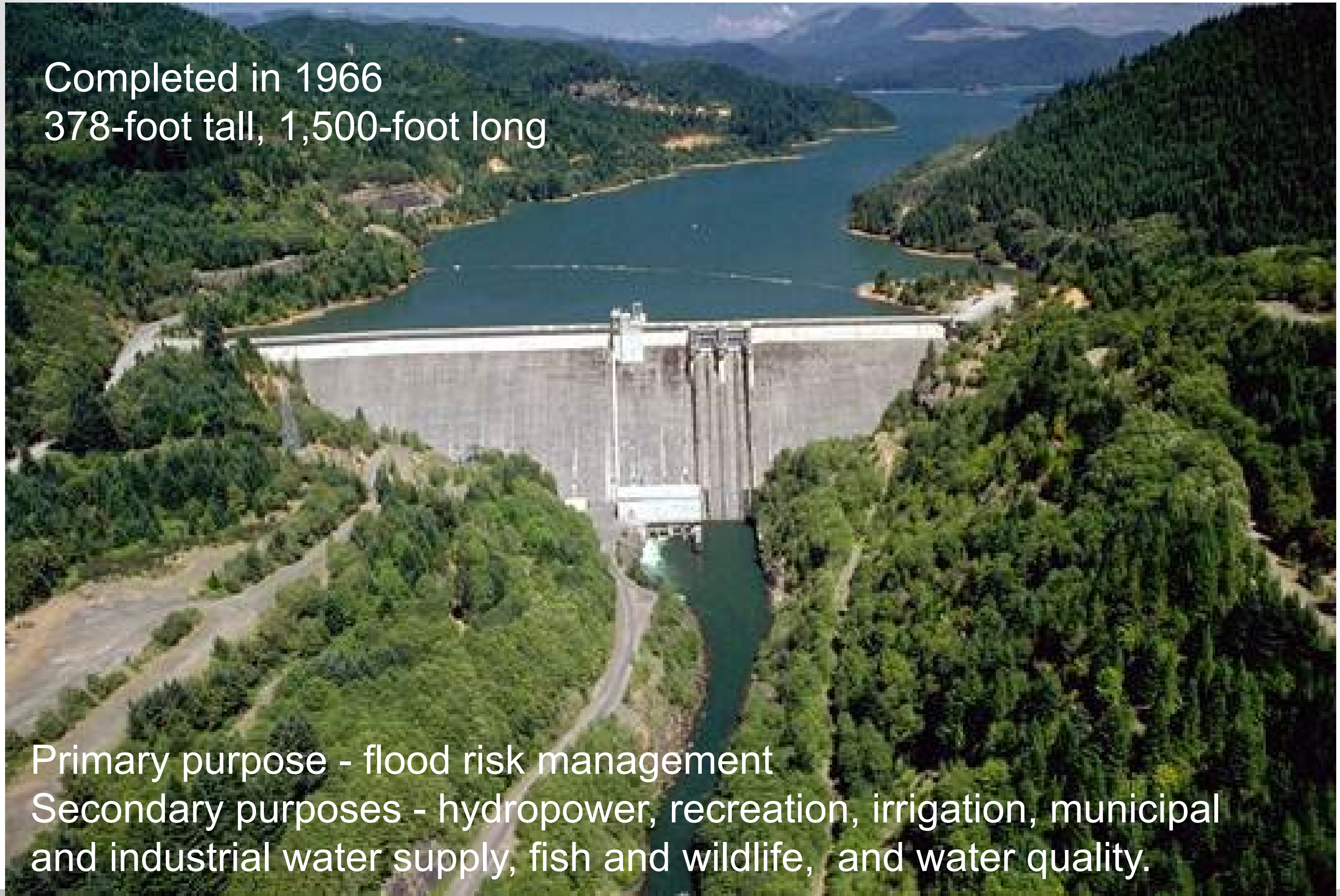
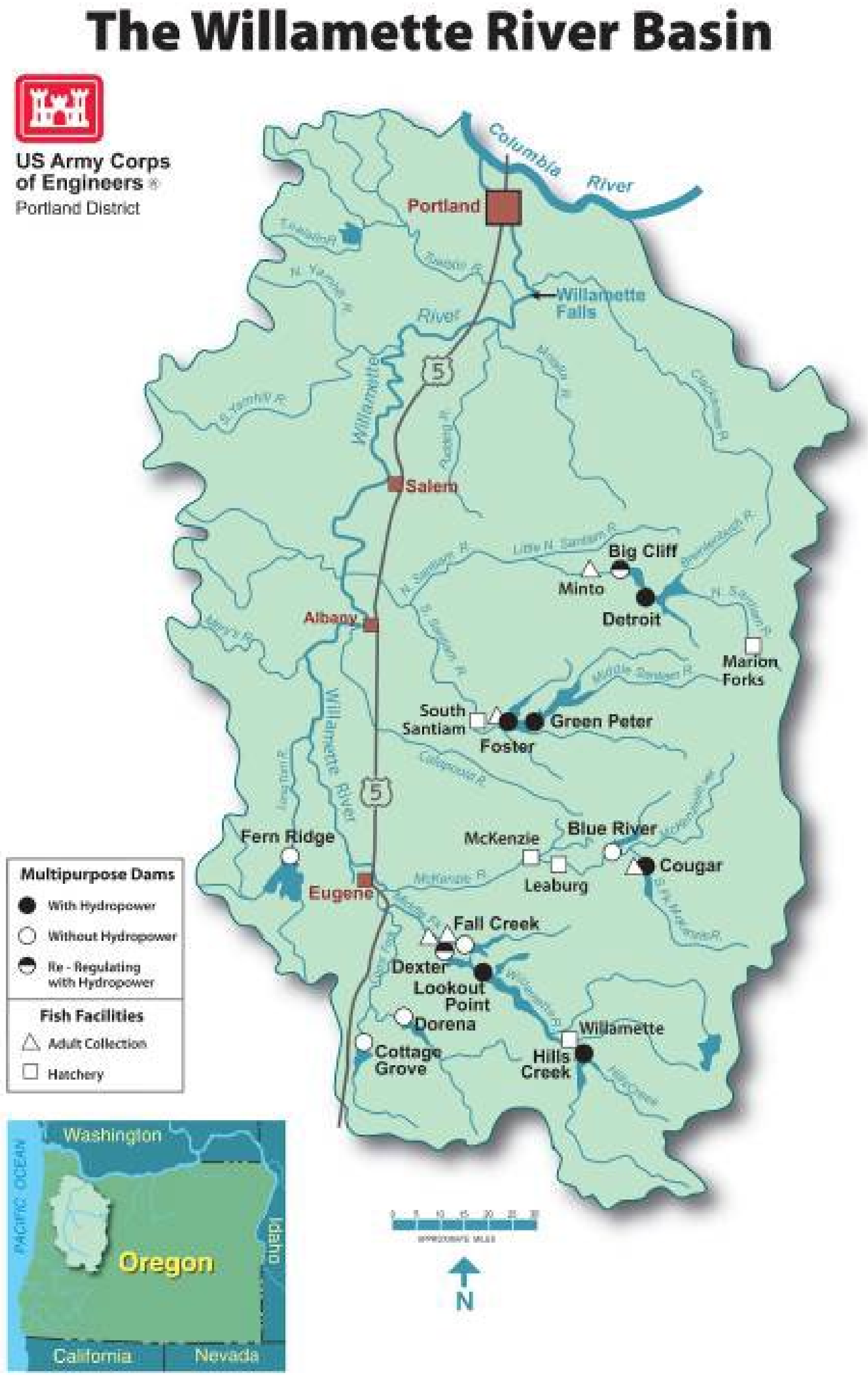


Completed in 1966
378-foot tall, 1,500-foot long

Primary purpose - flood risk management
Secondary purposes - hydropower, recreation, irrigation, municipal and industrial water supply, fish and wildlife, and water quality.



Green Peter Dam was constructed with adult and juvenile passage systems.

The system was abandoned in the late 1980's due to the inability to maintain naturally sustainable runs of spring Chinook and winter steelhead above the dam, in part from:

- poor adult collection in the tailrace cause by cold water discharge
- apparent low in-reservoir survival of juveniles

Despite these issues, the Green Peter Dam downstream fish passage system provides innovative features worth revisiting, and surprising performance for juvenile Chinook at a high head dam.

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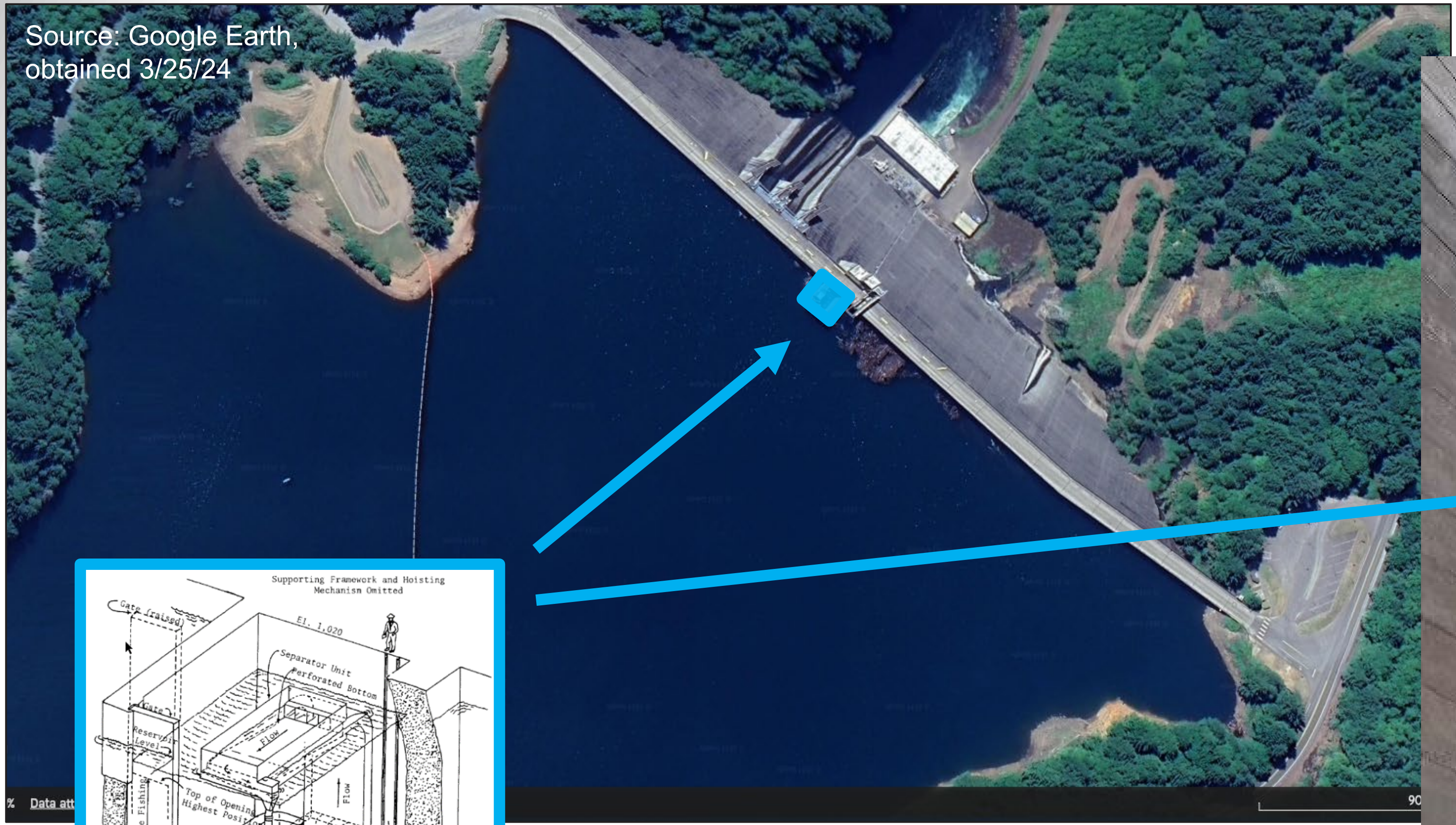
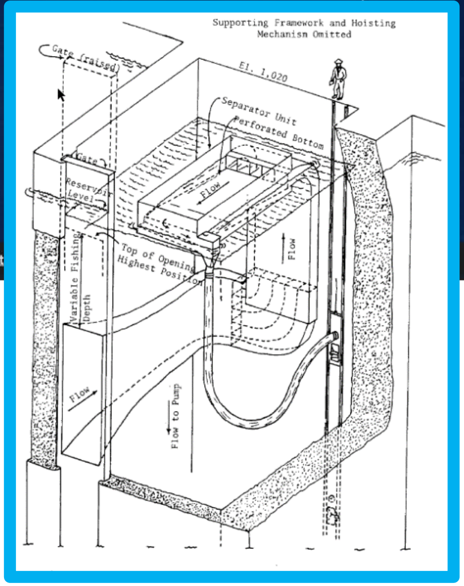
PURPOSE OF PRESENTATION

To inform future design efforts at high-head dams, this talk will –

- Review the Green Peter juvenile downstream fish passage system
- Compare performance of the Green Peter system to other surface collectors

GREEN PETER JUVENILE PASSAGE SYSTEM





GREEN PETER JUVENILE PASSAGE SYSTEM

Operational from max. pool elevation (1015) to min. conservation pool (922).

Entrance depth adjustable from 15 to 30 ft deep (center line).

Separator device (perforated screen) hinged for operational versatility.

6-10 cfs thru 12 in flexible hose attached to one of four 12-inch lateral pipes

Captured fish enter a trough at the end of the separator leading to 12 in flexible hose.

Remaining 190 to 194 cfs passed to collector well and returned via pumps to the forebay.

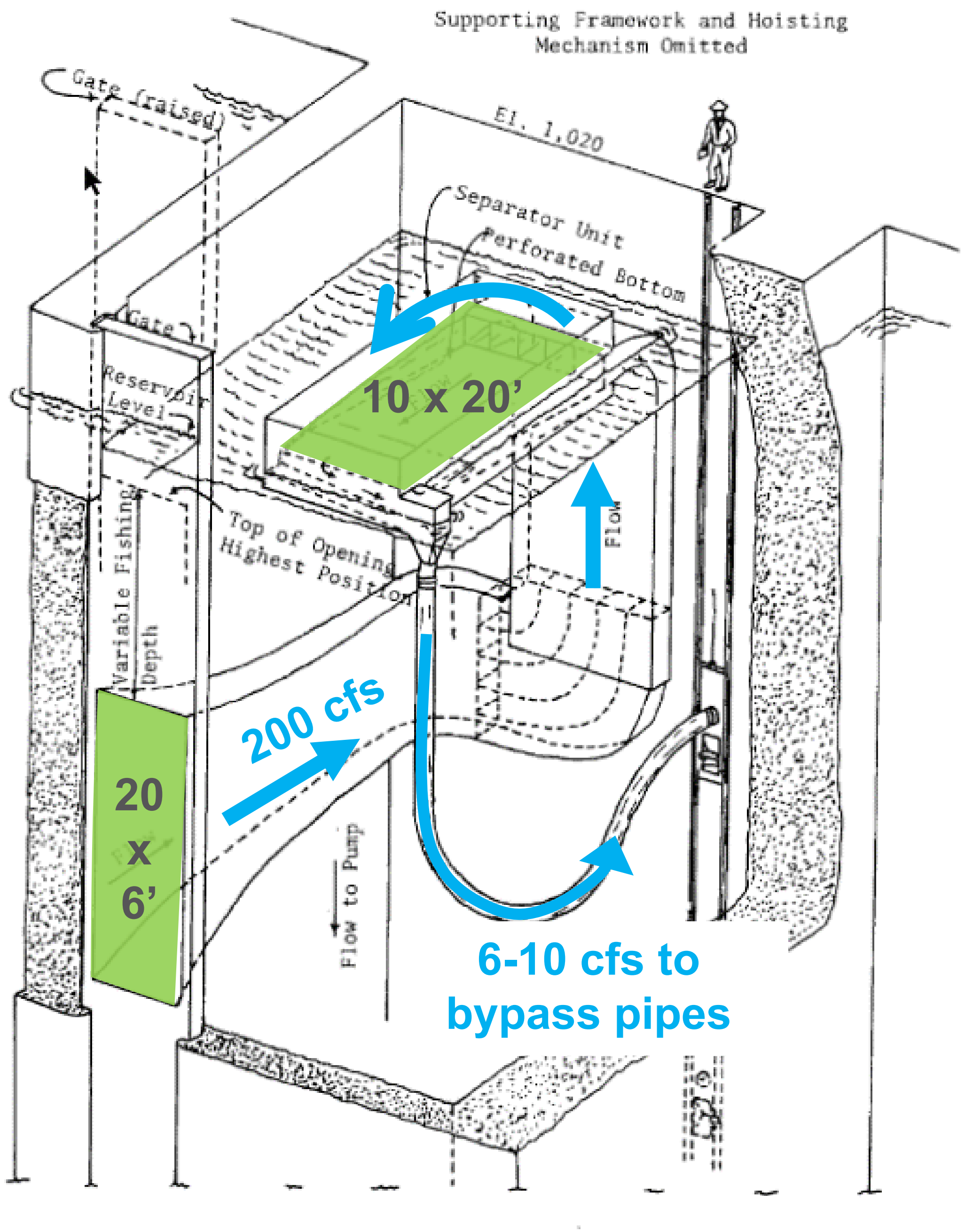


Figure 10. Diagram of Green Peter Downstream-Migrant Collection Horn and Separator Unit

Source: USACE (1962)

GREEN PETER JUVENILE PASSAGE SYSTEM

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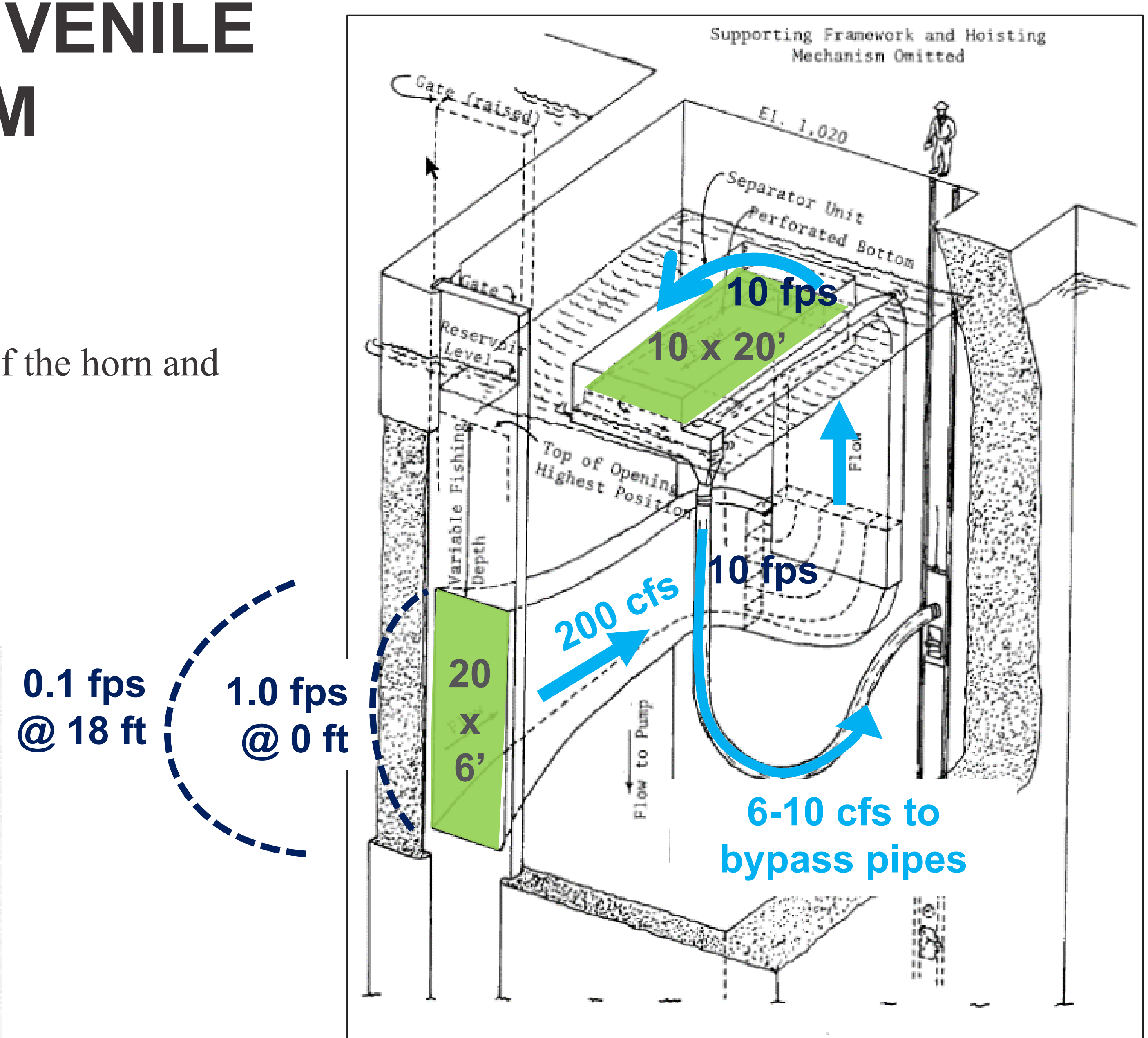
Approach and internal velocity

- 0.1 fps 18 ft from the horn
- ~1 fps at entrance
- Increases to about 10.0 fps at the throat of the horn and across the separator screen.

Flow net and internal velocities (USACE 1962)

FLOW NET SQUARE LOCATION	ATTRACTION FLOW 200 CFS ℄ OF HORN BELOW WATER SURFACE 15 FT AVERAGE VELOCITY	15 FT ΔV/FT	30 FT AVERAGE VELOCITY	30 FT ΔV/FT
A	0.030	0.008		
B	0.040	0.003		
C	0.060	0.005		
D	0.090	0.010		
E	0.140	0.020		
F	0.240	0.045		
G	0.430	0.127		
H	0.900	0.270		
I			0.030	0.002
J			0.050	0.003
K			0.080	0.009
L			0.140	0.024
M			0.280	0.055
N			0.560	0.162
O			1.210	0.287

DISTANCE DOWNSTREAM FROM UPSTREAM END OF HORN IN FEET	ATTRACTION FLOW 200 CFS AVERAGE VELOCITY	ΔV/FT
0	1.667	0.208
2	2.092	0.217
4	2.538	0.231
6	3.014	0.246
8	3.521	0.260
10	4.056	0.276
12	4.622	0.290
14	5.217	0.306
16	5.843	0.321
18	6.500	0.336
20	7.188	0.352
22	7.907	0.368
24	8.658	0.384
26	9.442	0.399
28	10.256	0.415



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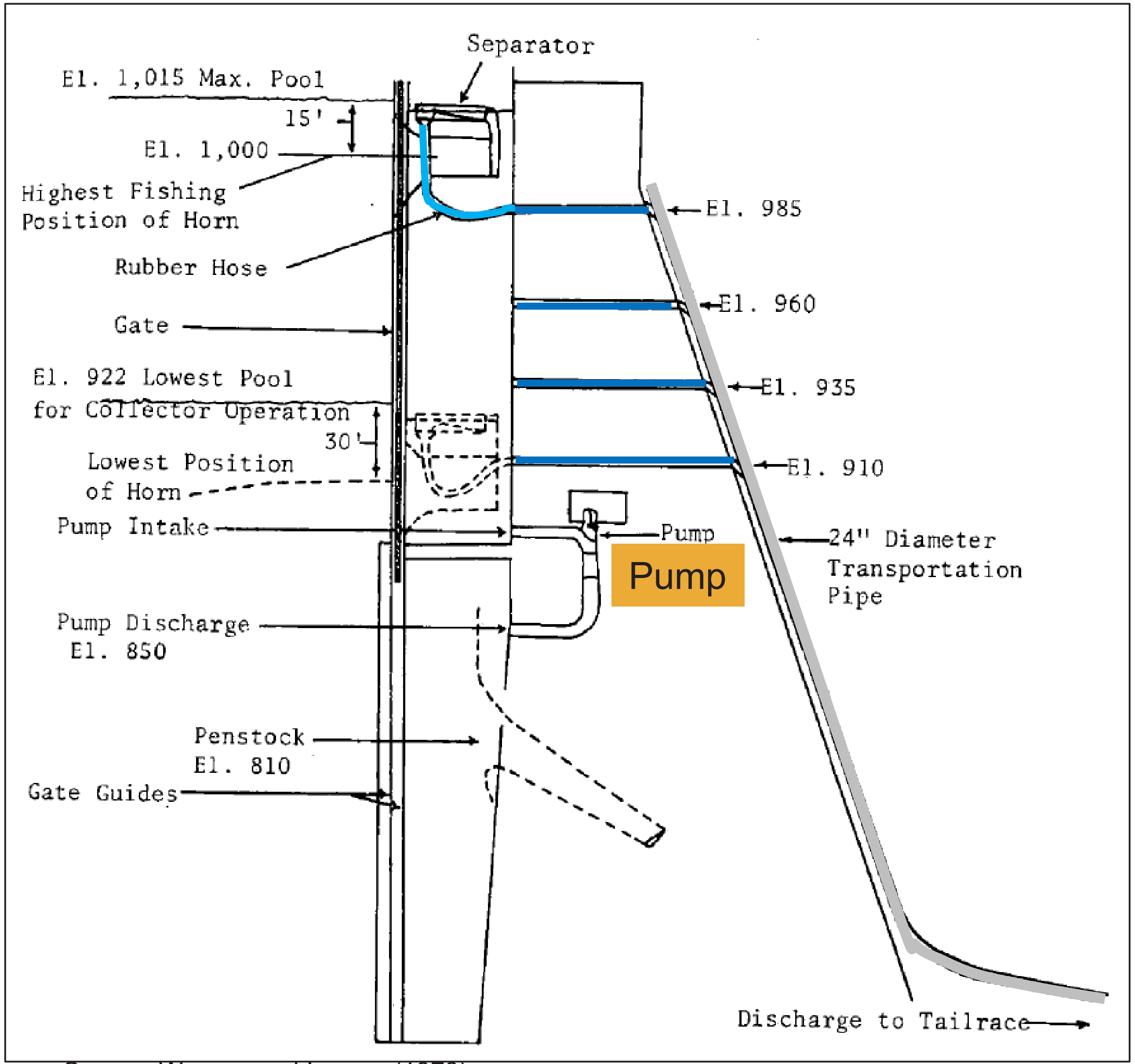
GREEN PETER JUVENILE PASSAGE SYSTEM

12 in. flexible hose connects to one of the four lateral pipes, depending on forebay elevation.

From the lateral pipes fish and water enter the stainless-steel transport pipe on the downstream face of the dam.

At the downstream end of the powerhouse the stainless-steel pipe changes to vinyl-lined iron pipe, extending 300 feet downstream (deceleration zone) to a rubber-lined chute leading to the tailrace.

Flow is provided by two 100-horsepower pumps. Both in operation creates a water surface difference of ~3.5 to ft between the forebay and the well, causing water to flow into the horn through and across the separator unit.



Source: Wagner and Ingram (1973)

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PASSAGE PERFORMANCE- JUVENILE CHINOOK

Collection Efficiency   Wagner and Ingram (1973)

METHODS - Batch marked hatchery juvenile Chinook released to forebay or head of reservoir. Recaptures occurred at the end of the transport pipe by sub-sampling a portion passing downstream.

RESULTS - 75 to 84% recovered among four groups
82 to 84% forebay collection efficiency

"Total emigration of chinook coho and sockeye was generally low each year compared to the number of fish planted in the reservoir."

"We believe the relatively small number of these emigrants reflected natural mortality in the reservoir and not low collection efficiency of the transport system"

Table 5. Efficiency of Collection, Downstream-Migrant Facility, Green Peter Dam, 1968-70

Mark	Release Date	Source	Release Area: Upper Res.	Release Area: Forebay	No. Released	No. Recovered 1/: Primary Migration	No. Recovered 1/: Residual Migration	Total	% Recovered
					SPRING CHINOOK				
AD	4/68	Hatch.	X		10,469	7,879	- 2/	7,879	75.3
AN	4/68	"		X	10,458	8,620	- 2/	8,620	82.4
Blue Dart	3/69	"	X		9,828	8,057	29	8,086	82.3
Brown Dart	3/69	"		X	4,869	4,088	11	4,099	84.2

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PASSAGE PERFORMANCE- JUVENILE CHINOOK

Bypass system survival and injuries

Wagner and Ingram (1973) –
Enumerated direct mortalities in evaluator at end of transport pipe. Survival estimates (in Table) were affected by early debris problems, rusted pipe, and conditions in the evaluator. Found mortality to be minimal after addressing these issues.

Liss et al. (2022) –
Treatment groups of healthy and copepod infected juvenile surrogate Chinook were released from holding tanks through a flexible tube connected to the original lateral and transport pipe bypass system.

Source	Survival (%)
Wagner and Ingram	95.1 to 97.7
Liss et al.	97.8 to 98.9

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COMPARISON - JUVENILE CHINOOK FOREBAY COLLECTION EFFICIENCY (FCE)

Project	High head dam[1]	Volitional passage	Annual pool fluctuation (m)	Accessible forebay[2] (Ha)	Inflow (m^3/s)	Entrance area (m^2)	Chinook FCE
River Mill Dam		Y	<1	7	14.2	13.6	>95[3]
Green Peter	Y	Y	**27**	20.9	**5.7**	**11.0**	**82-84**[4]
North Fork Dam	Y	Y	<1	16	28.3	31.7	85 to 95[3]
Swift Dam	Y		15	139	16.9	19.8	44-52[5]
Round Butte Dam	Y		1	38	0-170	223.3	51[6]

1. >30 m hydraulic head
2. Accessible forebay at full pool
3. Ackerman (2023)
4. Wagner and Ingram (1973)
5. Four Peaks Environmental (2023) CE Report
6. Kock et al. (2019)

Data sources for operational attributes:
Green Peter = USACE, 1962
All other sites = Kock et al. 2019

FACTORS AFFECTING FCE

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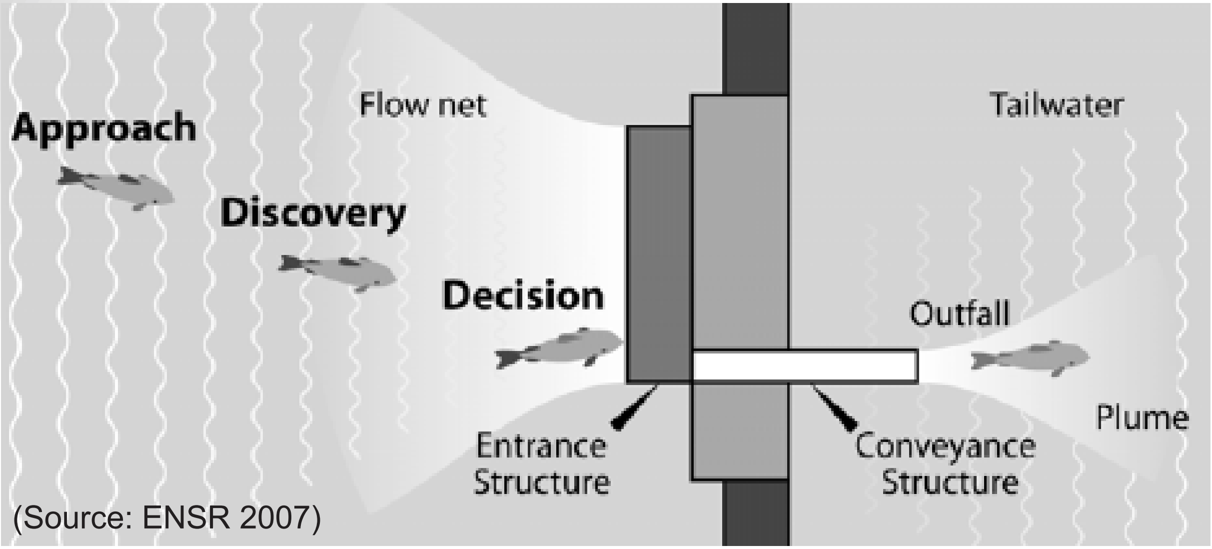
Surface outlet conceptual framework



Kock et al. (2019) found that the following factors were significant predictors of collection performance:

- Inflow (+),
- lead nets (+),
- collector entrance area (+),
- the relative size of the forebay (-),
- the interaction between collector entrance and forebay areas (+)

Model explained most of the variation in observed FCE (R^2 = 0.935) and fit the data well

Application of regression model to Green Peter Downstream Passage System

Model Estimate - **31 to 51%** (depending on if dam assumed to provide guidance similar to lead nets)
Field Estimate - **82 to 84%** Wagner and Ingram (1973)

WHAT EXPLAINS THE APPARENT HIGH FCE AT GREEN PETER?

Hypotheses

1) Approach, Guidance and Discovery
   a. Water currents and dam discharge - no competing surface flow
   b. Entrance location – near dam face

2) Retention
   a. Fish are captured before exposure to dewatering screen
   b. Mechanical noise appears limited – pumps located at depth

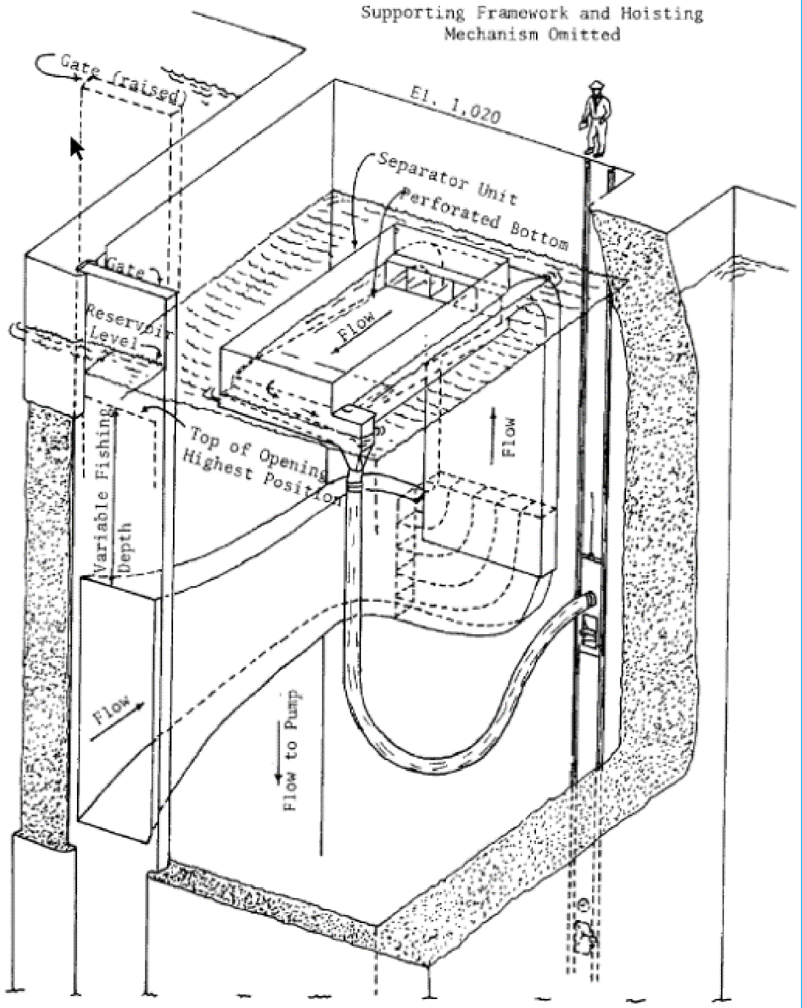


Figure 10. Diagram of Green Peter Downstream-Migrant Collection Horn and Separator Unit

SUMMARY – GREEN PETER DOWNSTREAM PASSAGE SYSTEM

- Surface collection with volitional passage appears feasible for Chinook at Willamette dams, considering the original Green Peter system
- Present-day assumptions about FCE drivers need further investigation
- The system included innovative features, some that appear to have worked well despite inconsistency with contemporary design objectives:
  - Inflow
  - Collector horn location and design
  - Screen location and design
  - Pump location and design
  - Bypass design

FUTURE PLANS AND CONSIDERATION

Meta-analysis
Develop refined relationships between dam operating conditions and juvenile passage at Willamette dams

ELAM modeling
Develop a CFD model, apply the ELAM model to assess forebay and outlet condition effects on FCE

FBW modeling
Revise model structure and inputs; reapply for Green Peter and other dams

Future Consideration
Could the original Green Peter Juvenile Passage System be rebuilt to provide a field lab for further investigations?

Photo Source: J. Borden, USACE (2023)

Source: Google Earth, obtained 3/26/24

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THANK YOU, QUESTIONS?

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